



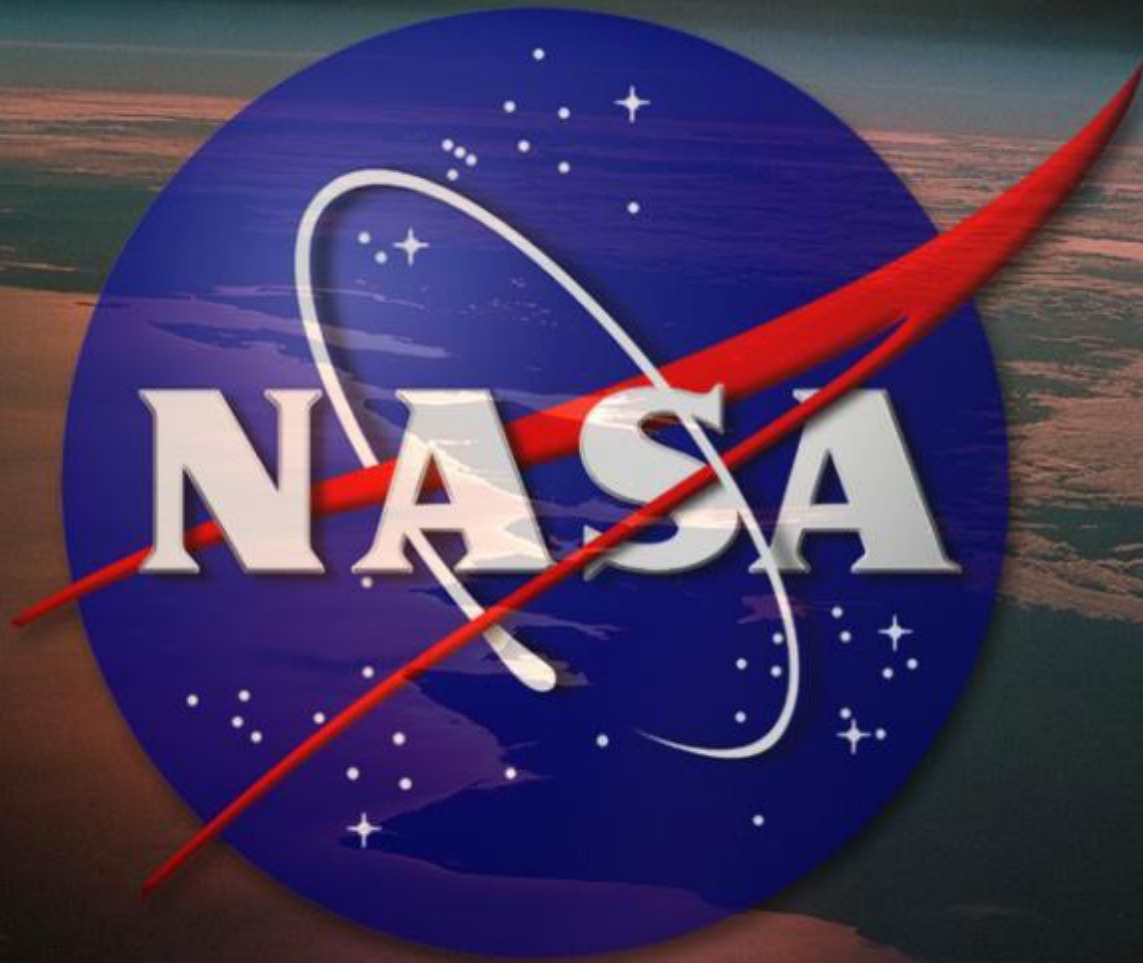
# STEM Adventure Weekend 2016

NASA/JSC/Tim Hall





# Welcome STEM Adventurers





# A little about the speaker...Tim Hall



- Born & raised in West Virginia
- Graduate of West Virginia University (WVU) School of Engineering with a BS Mechanical Engineering



*Lets Go Mountaineers!!*



- Involved in the space industry for 18+ years
- Space career includes working 30+ Space Shuttle and International Space Station (ISS) Missions in the Mission Control Center
- Currently Chief of the Extravehicular Activity (EVA) Operations Branch







# What's Going On Now At NASA?



# Human Spaceflight....

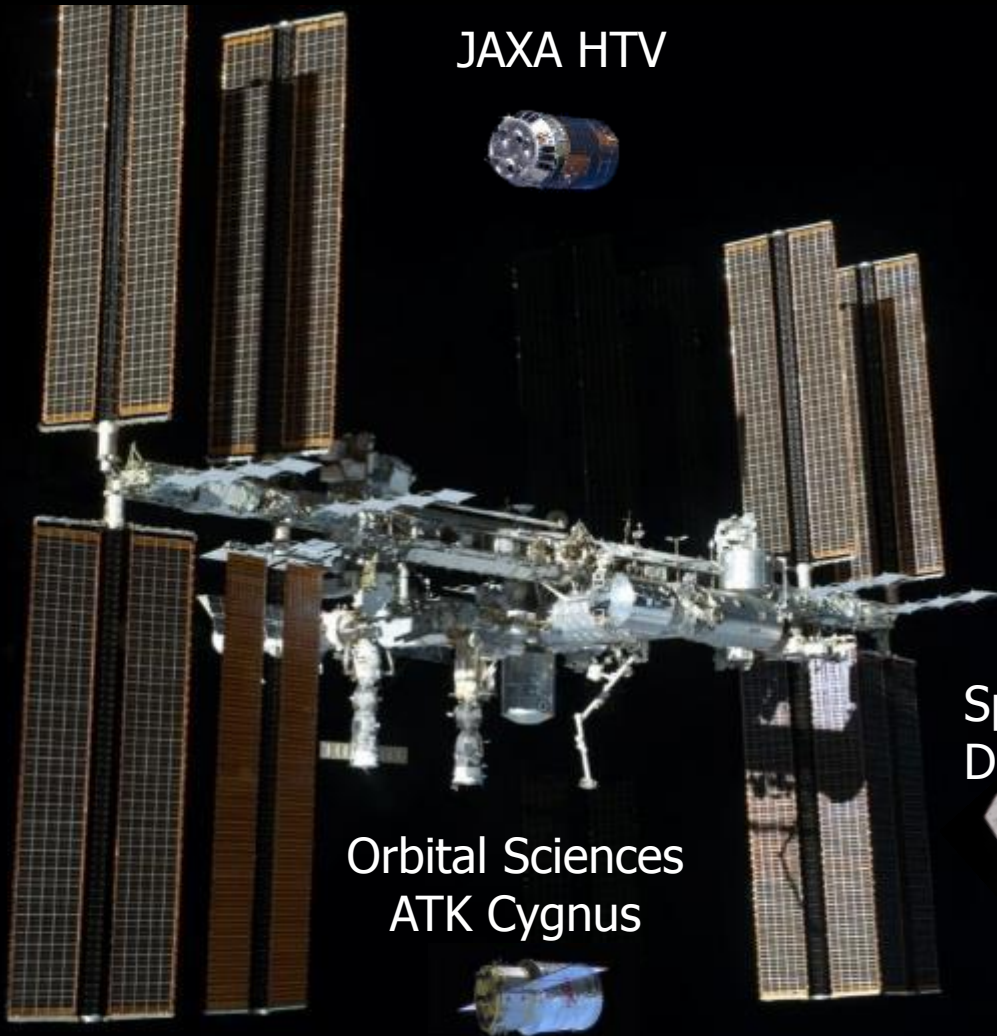


2000

224 humans have visited ISS!

2016

JAXA HTV



Orbital Sciences  
ATK Cygnus

SpaceX  
Dragon



Expedition 48

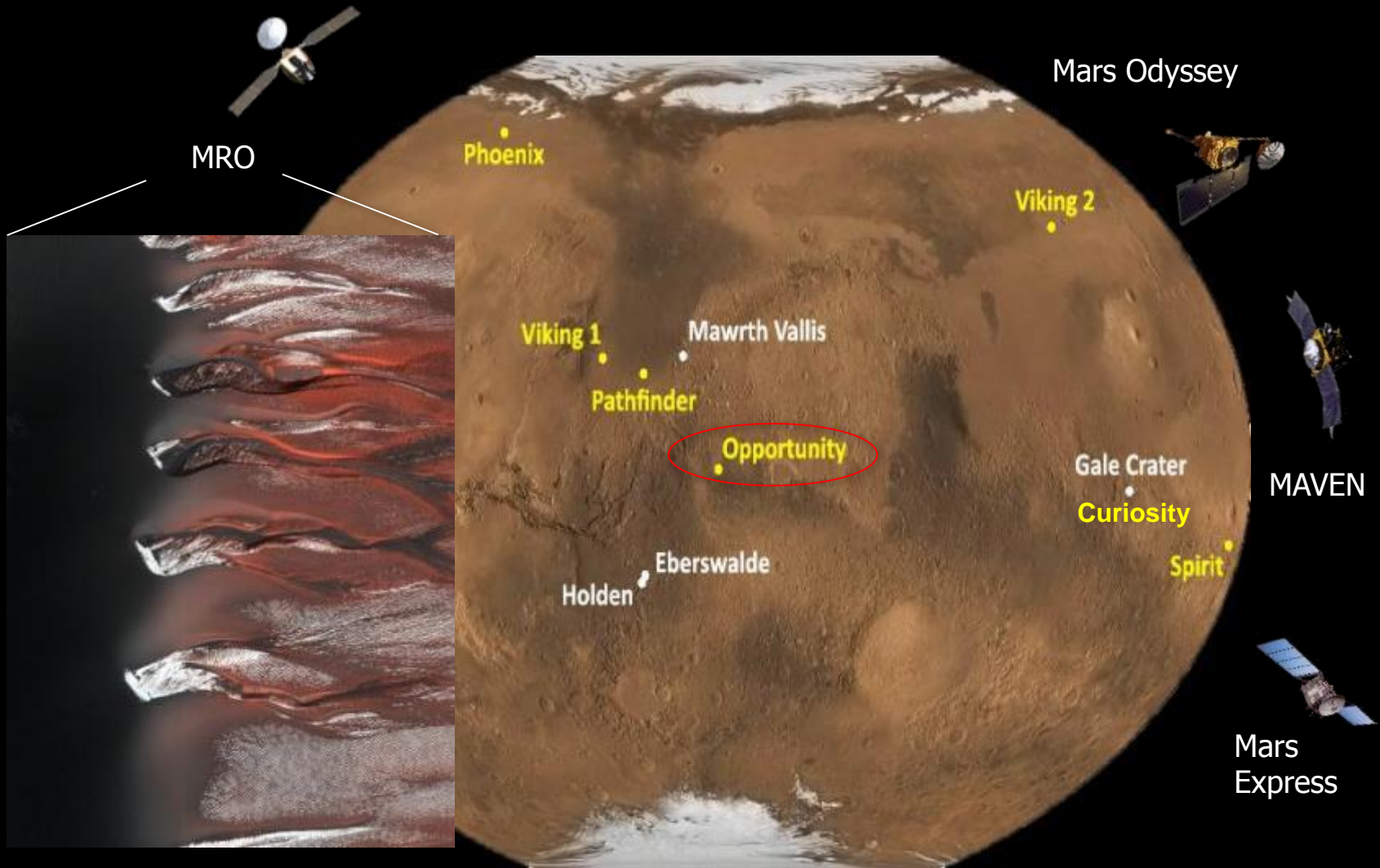


Expedition 49





# Planetary Missions, Mars is busy!...



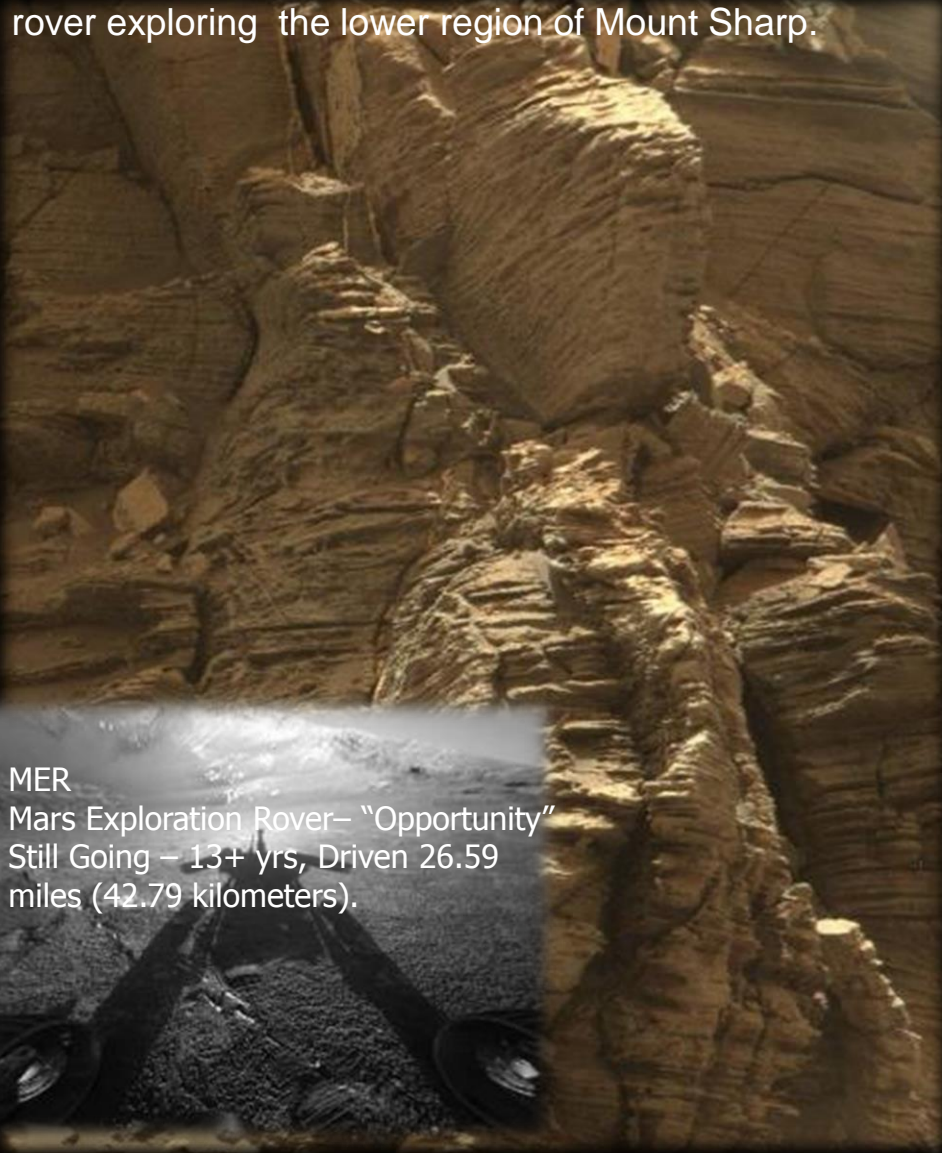
Kaiser Crater hosts a large field of sand dunes. Every winter the dunes are covered with a layer of seasonal carbon dioxide ice (dry ice)



# Planetary Missions, Mars is busy!...



The layered geologic past of Mars is revealed in stunning detail new images from NASA's Curiosity Mars rover exploring the lower region of Mount Sharp.



MER  
Mars Exploration Rover– "Opportunity"  
Still Going – 13+ yrs, Driven 26.59  
miles (42.79 kilometers).

MSL- Mars Science  
Laboratory  
"Curiosity"



MSL Selfie



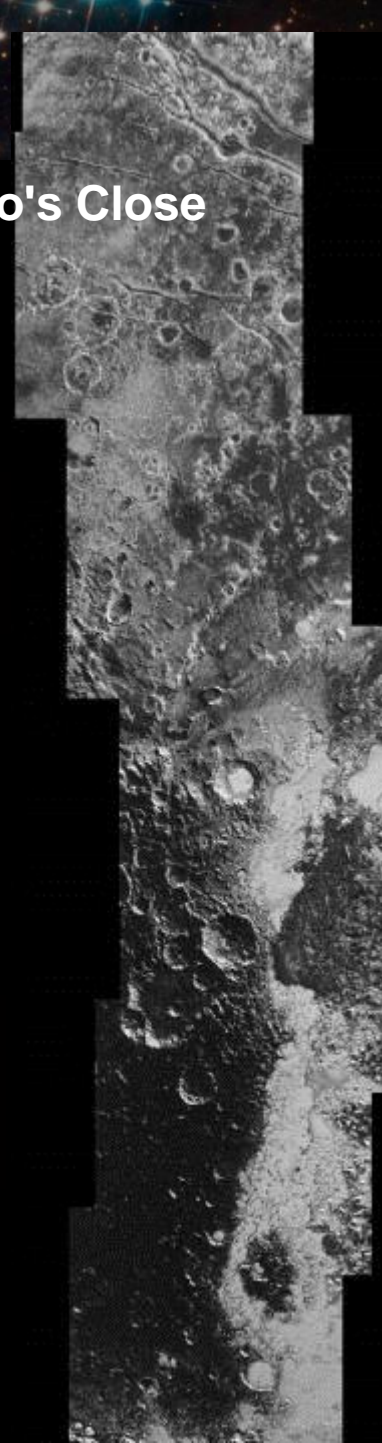
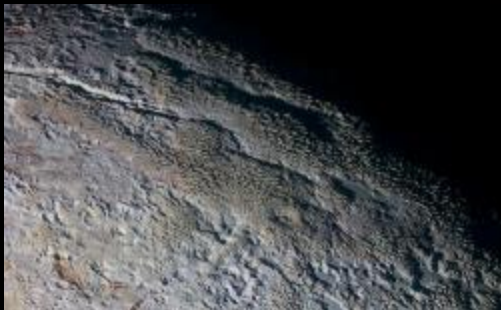
MSL Wear and Tear



# New Horizons @ Pluto!

- New from NASA's New Horizons: Increasing Variety on Pluto's Close Approach Hemisphere, and a 'Dark Pole' on Charon

NASA's New Horizons spacecraft passed Pluto in July 2015



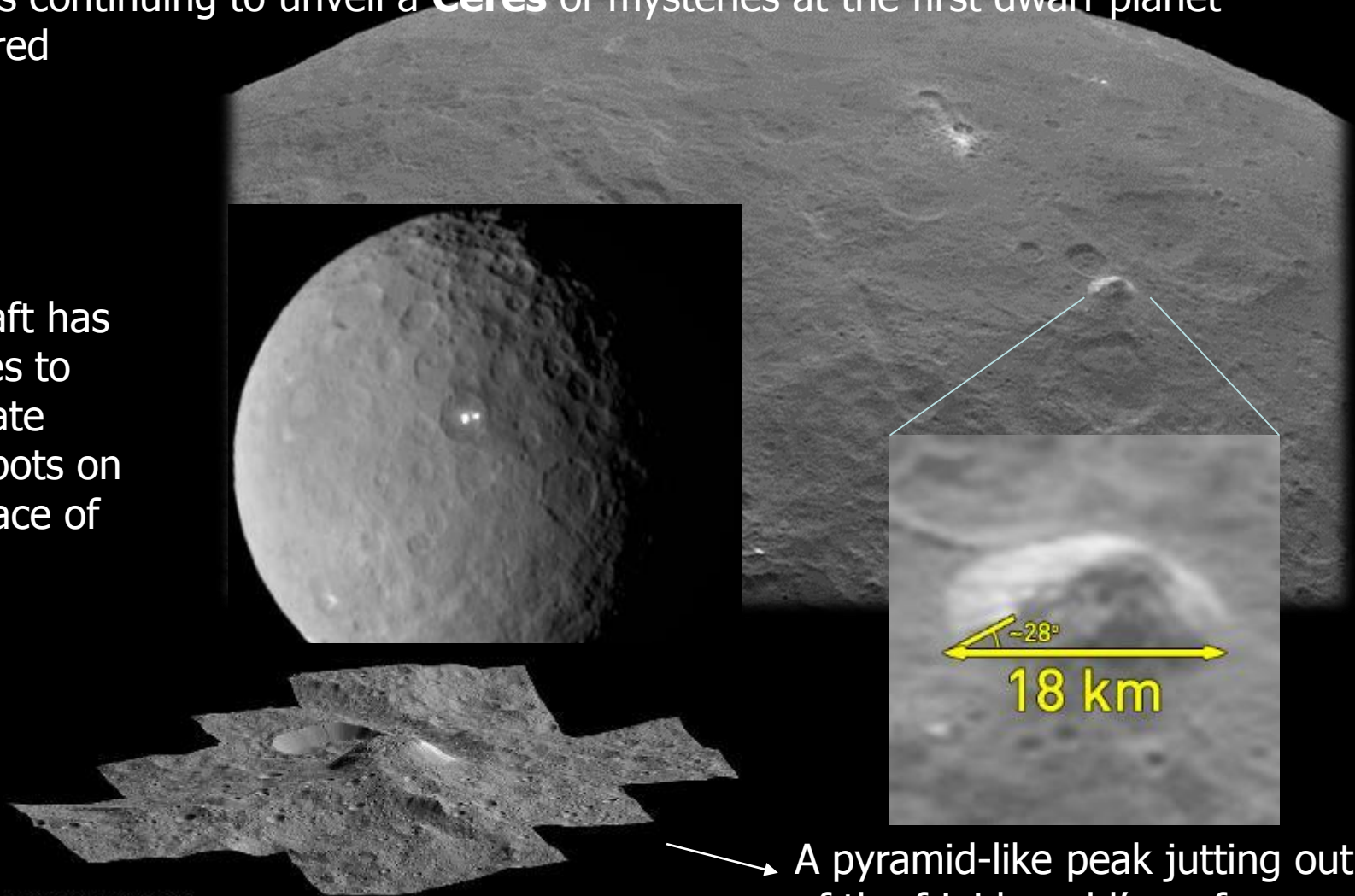


# Dawn Spacecraft @ Ceres



**Dawn** is continuing to unveil a **Ceres** of mysteries at the first dwarf planet discovered

**Dawn** spacecraft has continues to investigate bright spots on the surface of Ceres



© NASA/JPL-Caltech/USC/AMPO/OLICA

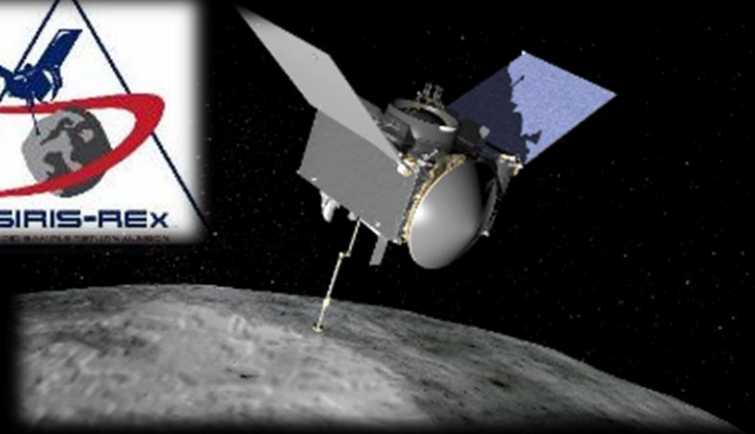
A pyramid-like peak jutting out of the frigid world's surface was discovered in 2015



# OSIRIS-Rex's Complex Route



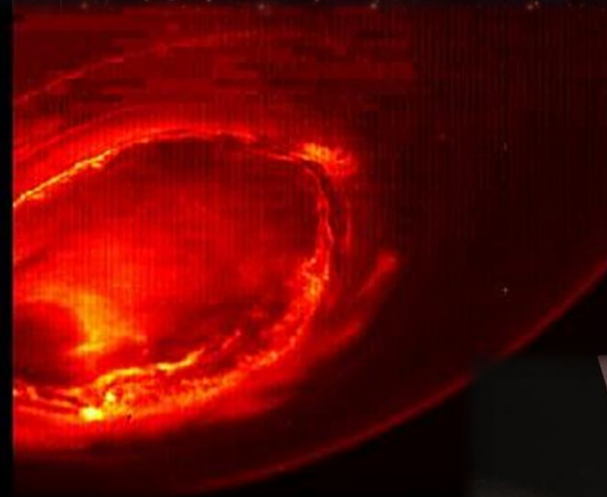
- The OSIRIS-REx spacecraft is designed to rendezvous with in Bennu in 2018, study the asteroid and return a sample to Earth in 2023
- This sample of a primitive asteroid will help scientists understand the formation of our solar system more than 4.5 billion years ago
- As of one week post launch (Sept 15<sup>th</sup> 2016) , the spacecraft was approximately 2 million miles (3.2 million kilometers) ) from Earth, traveling at approximately 12,300 miles per hour (19,800 kilometers per hour) relative to Earth



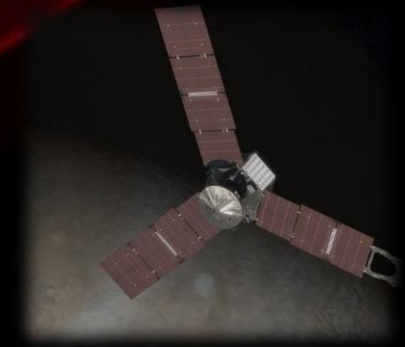


# Juno – Jupiter rendezvous

- Juno is a NASA New Frontiers mission currently on station (arrived July 4th 2016) orbiting the planet Jupiter
- The spacecraft is in a polar orbit to study Jupiter's composition, gravity field, magnetic field, and polar magnetosphere
- Juno will also search for clues about how the planet formed, including whether it has a rocky core, the amount of water present within the deep atmosphere, how its mass is distributed, and its deep winds (~400 mph)



This infrared image of the southern aurora of Jupiter, as captured by NASA's Juno spacecraft on August 27, 2016





# Many, many other cool missions...



Just a few to mention...



Cassini

Saturn orbit, last year of operation

Juno  
Arriving at Jupiter July 2016



Hubble

Still researching origins of the universe

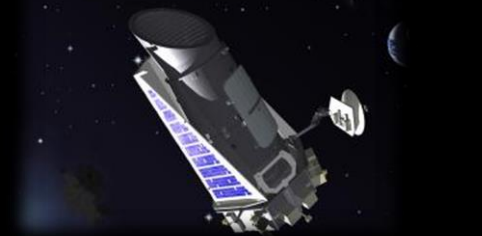


Kepler

Planet Count

Confirmed Planets: 977

Planet Candidates: 4,234



Voyager 1

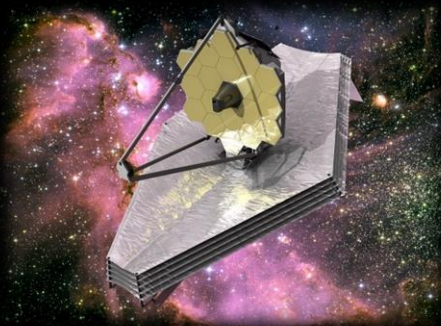
Has left the building...

Traveling interstellar space



James Webb Telescope

Launch in 2018



Eyes on the Solar System

<http://eyes.nasa.gov/>





# Extravehicular Activity (EVA) Hardware & Operations Overview





# Definition of Extravehicular Activity (EVA)



**Definition:** Astronaut leaves the protective environment of a pressurized spacecraft and ventures out into vacuum of space wearing an extravehicular spacesuit.

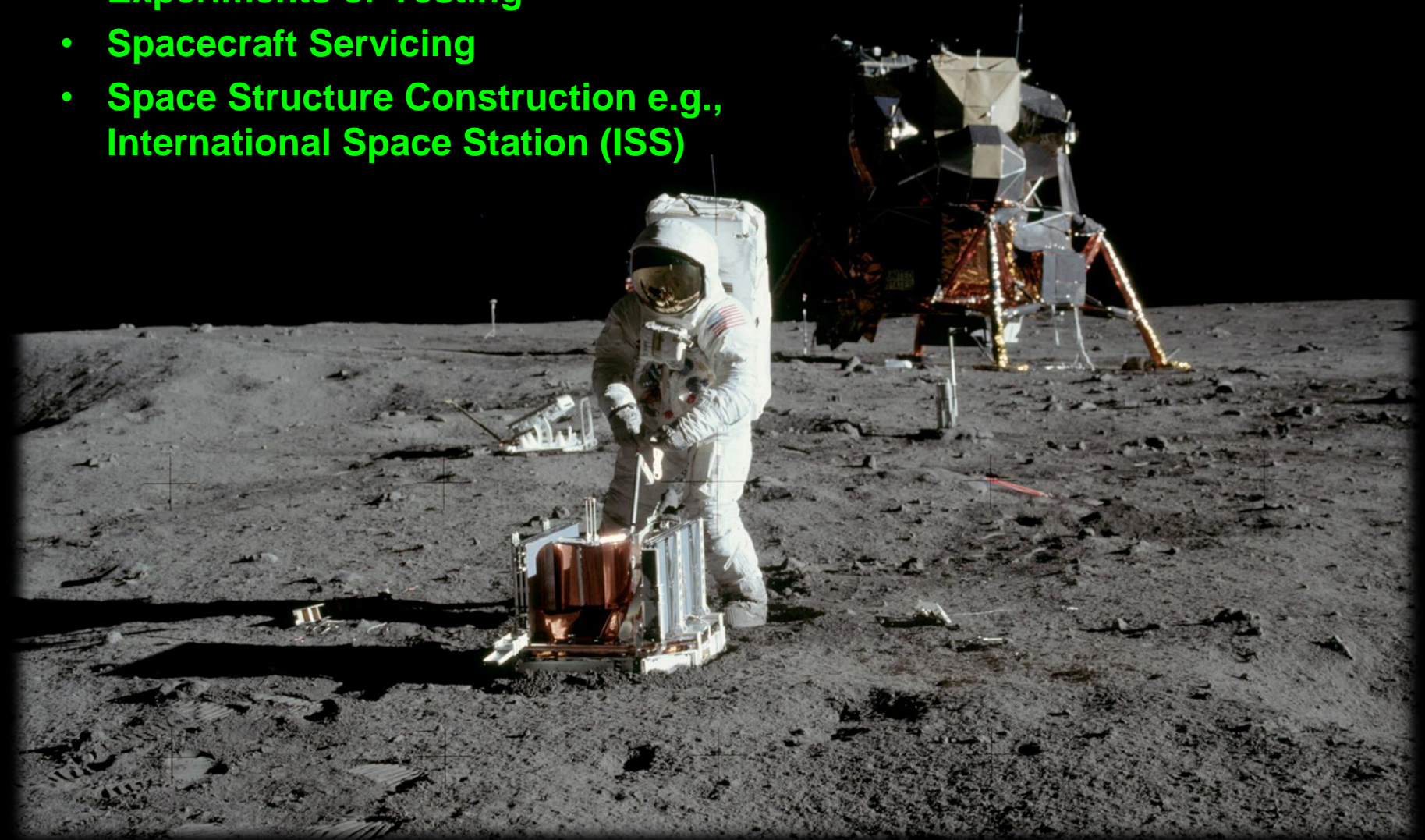




# Purpose of EVA



- Contingency or Mission Success Repairs
- Experiments or Testing
- Spacecraft Servicing
- Space Structure Construction e.g., International Space Station (ISS)

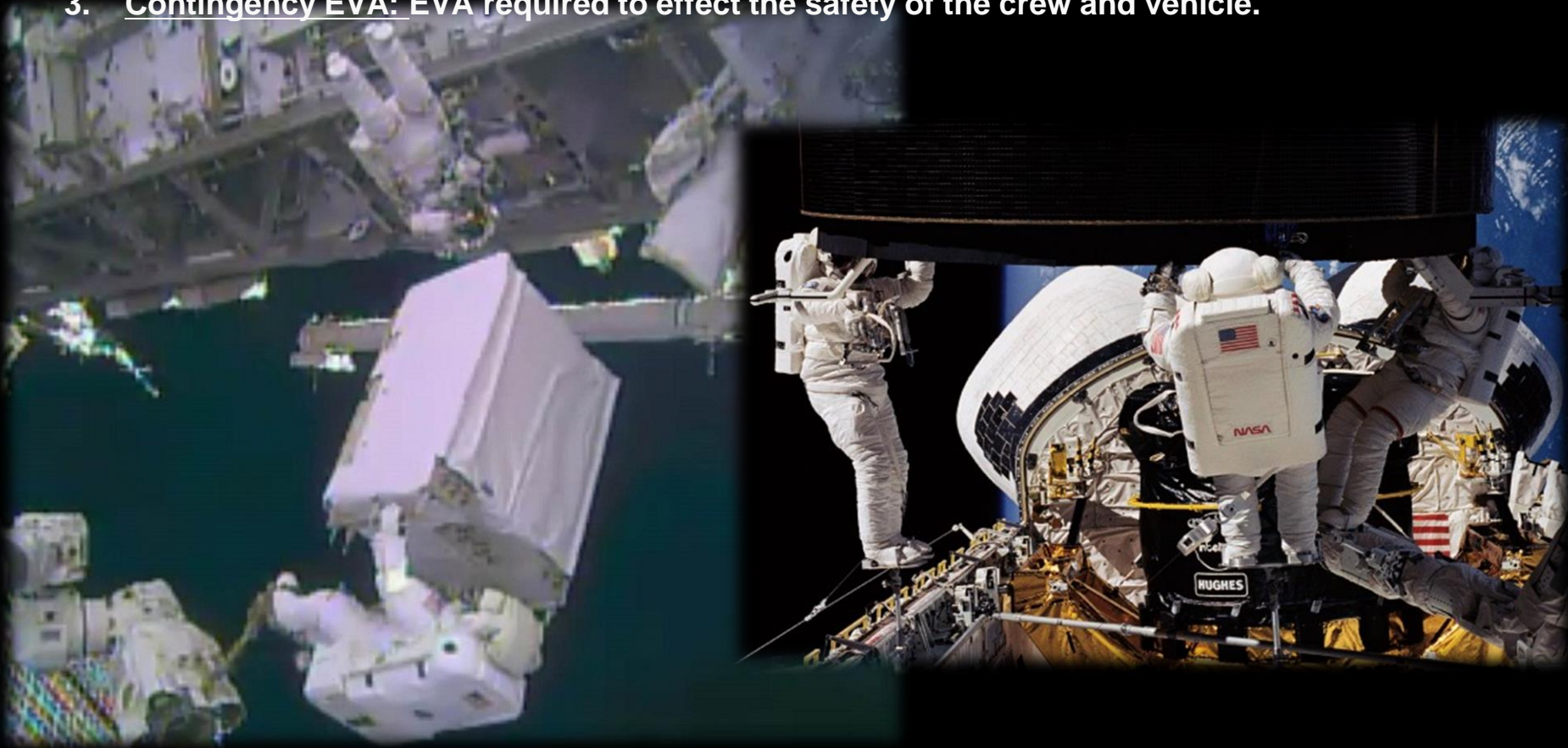




# EVA Categories



- Three basic categories of EVA:
  1. Scheduled EVA: EVA planned and trained prior to launch and included in the mission timeline.
  2. Unscheduled EVA: EVA, although trained, not included in the scheduled mission activities, but which may be required to achieve mission or operational success.
  3. Contingency EVA: EVA required to effect the safety of the crew and vehicle.





# Definition of Spacesuits



- Spacesuits
  - Typically, 2 types of pressurized “spacesuits” have been constructed to support NASA programs
- Launch, entry, and abort (LEA) spacesuit
  - Used to protect crewmembers from launch, ascent, abort, landing and other dynamic loading.
  - Capable of providing protection from loss of cabin pressure and crew rescue following landing.
- Extravehicular Activity (EVA) spacesuit
  - Used to allow crewmembers to work effectively in the harsh external space environment (provides protection from vacuum, thermal, micrometeoroids, radiation, etc.).





# Historical Overview – First EVA



- First EVA was conducted by USSR/Alexi Leonov on March 18, 1965.
  - Many EVAs have since been accomplished by the Soviet Union & Russia continuing into the International Space Station era.





# Historical Overview -U.S. EVA Experience



## Gemini EVA Experience -

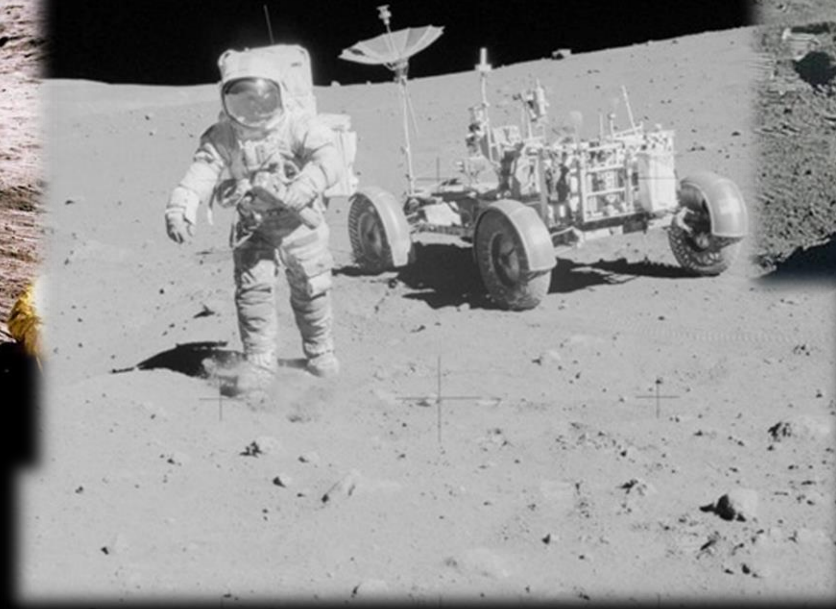
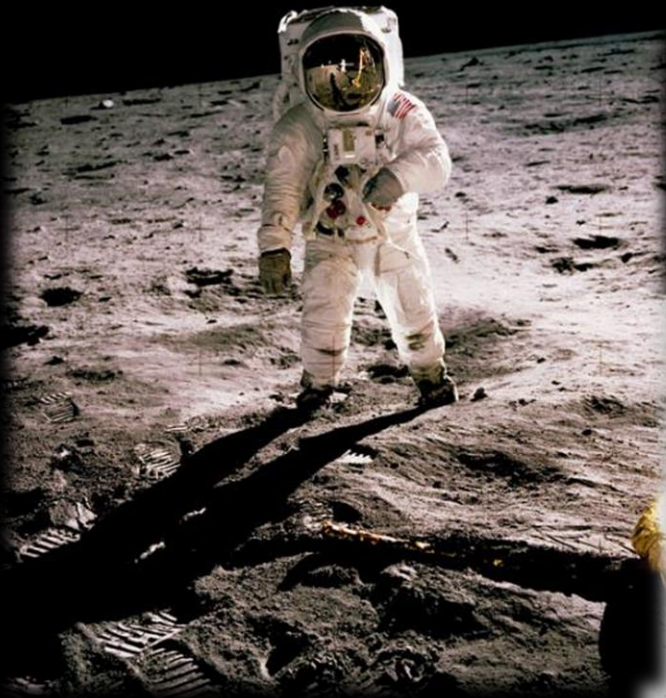
- Astronaut Edward White II performed first U.S. EVA during Gemini IV June 3, 1965 (22 min) and coined the term “Spacewalk”
- Proved EVA to be a viable technique for operations outside the spacecraft crew compartment.
- Problems encountered: helmet fogging, overheating due to high metabolic activity (primarily due to suit constraints and lack of training).



# Historical Overview - Apollo EVA Experience



- Spacesuit was redesigned to allow greater mobility.
- Suit used for lunar and in-space EVAs.
- Suit was configured with its own portable life support system providing:

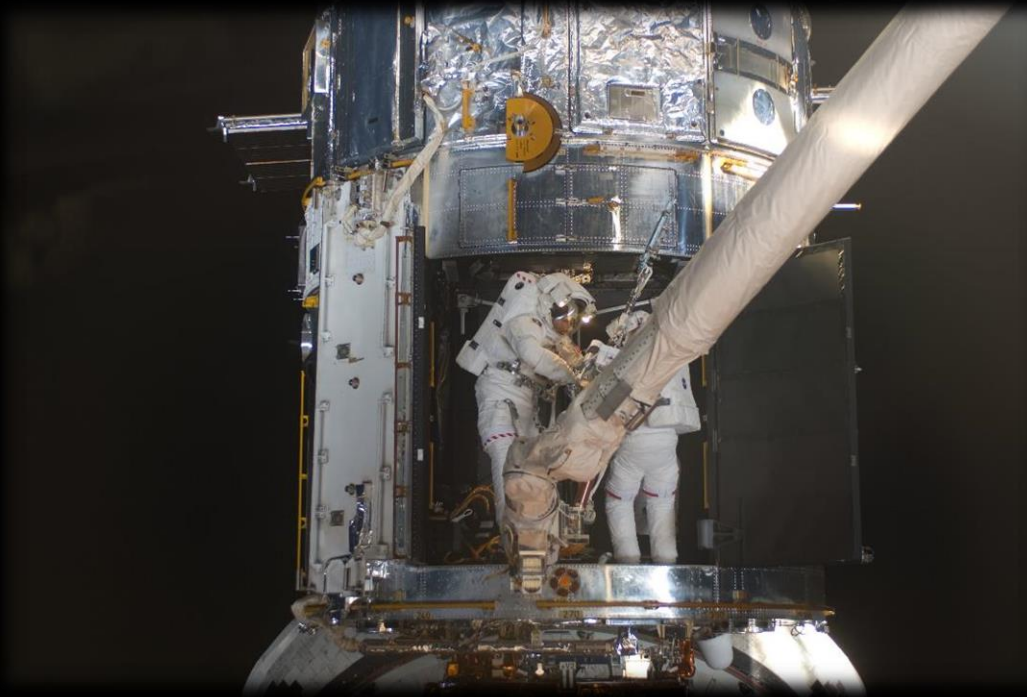




# Historical Overview



- Skylab EVA Experience
  - Umbilical replaced portable life support system and provided breathing oxygen, cooling, and served as a tethering device.
  - 10 EVAs were performed during the 3 Skylab missions totaling 82.5 hours.
- Space Shuttle EVA Experience
  - New space suit design for additional mobility and modularity
  - Portable life support system designed for microgravity operation

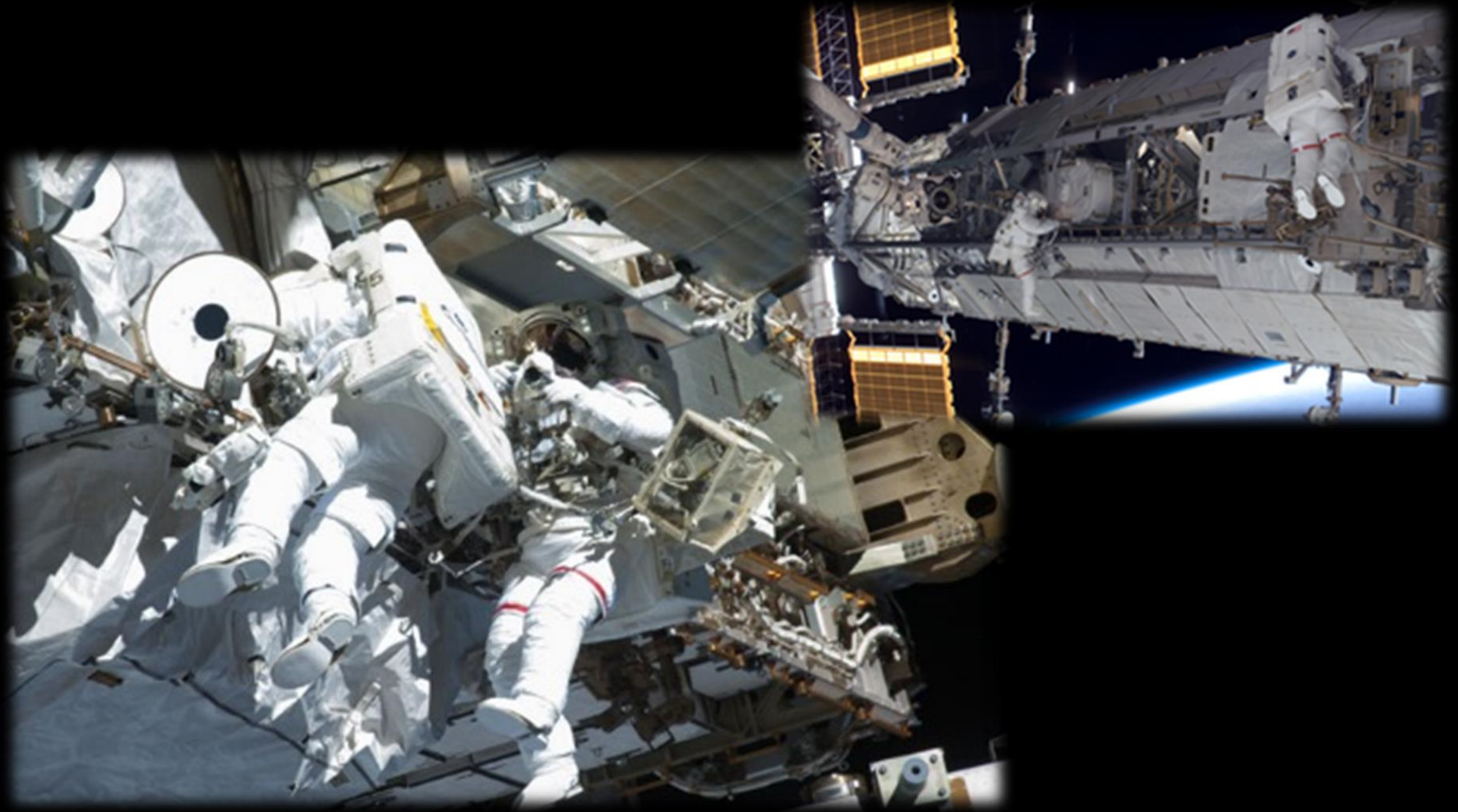




# Historical Overview



- International Space Station (ISS) EVA Experience
  - EMU certified for extended duration on-orbit operations (25 EVAs).
  - Orbital Replacement Unit (ORU) capability added.
  - Accumulated 1000s of hours of EVA experience over 150+ EVAs





# Historical Overview Apollo EVA Experience



Walking on the moon?



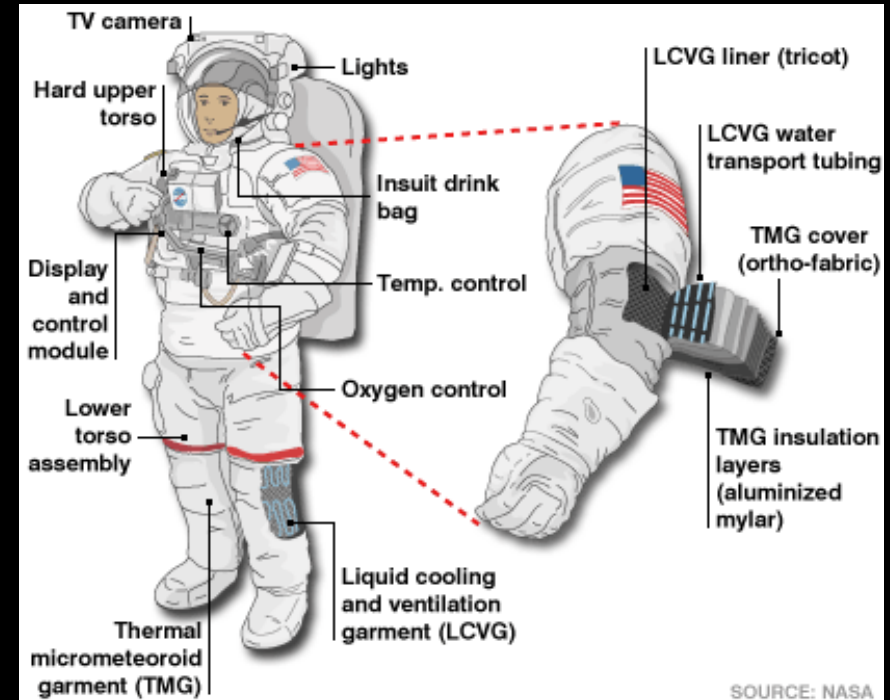
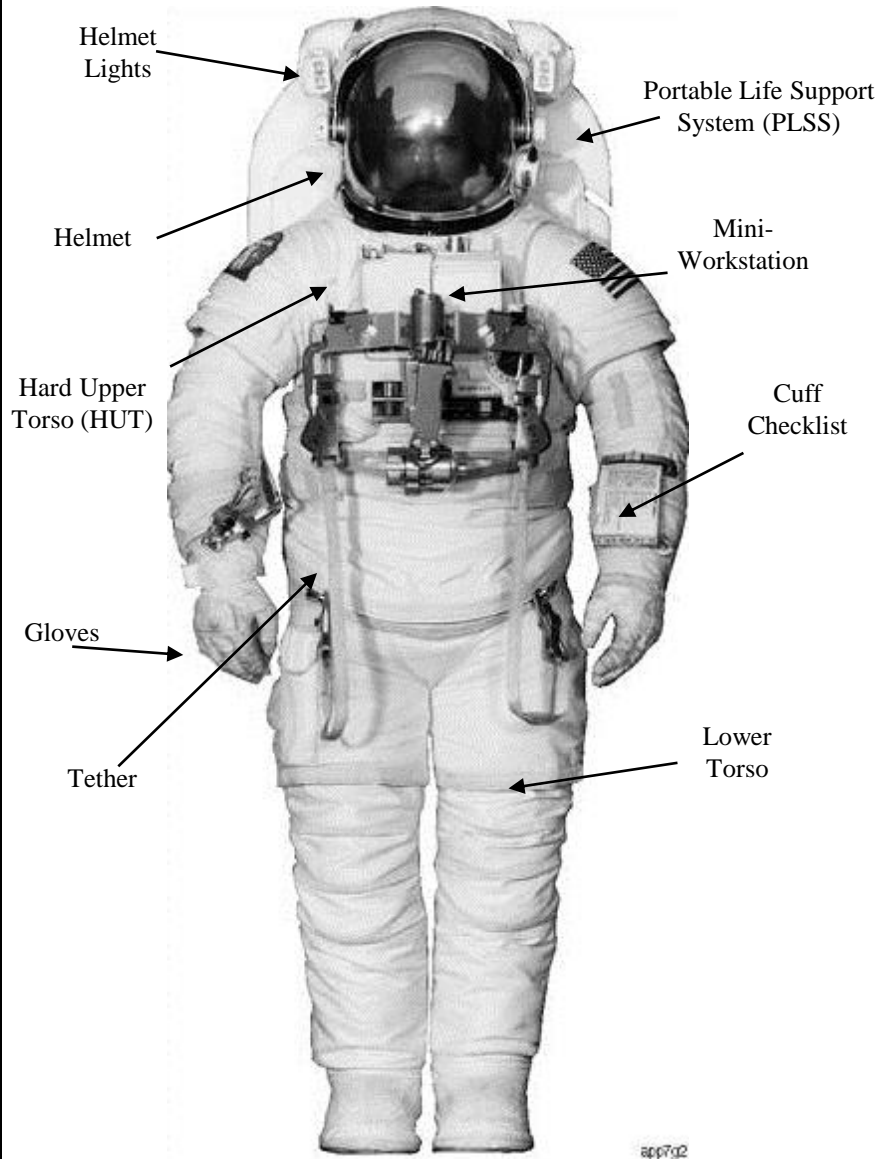
# Historical Overview Apollo EVA Experience



Falling on the moon?



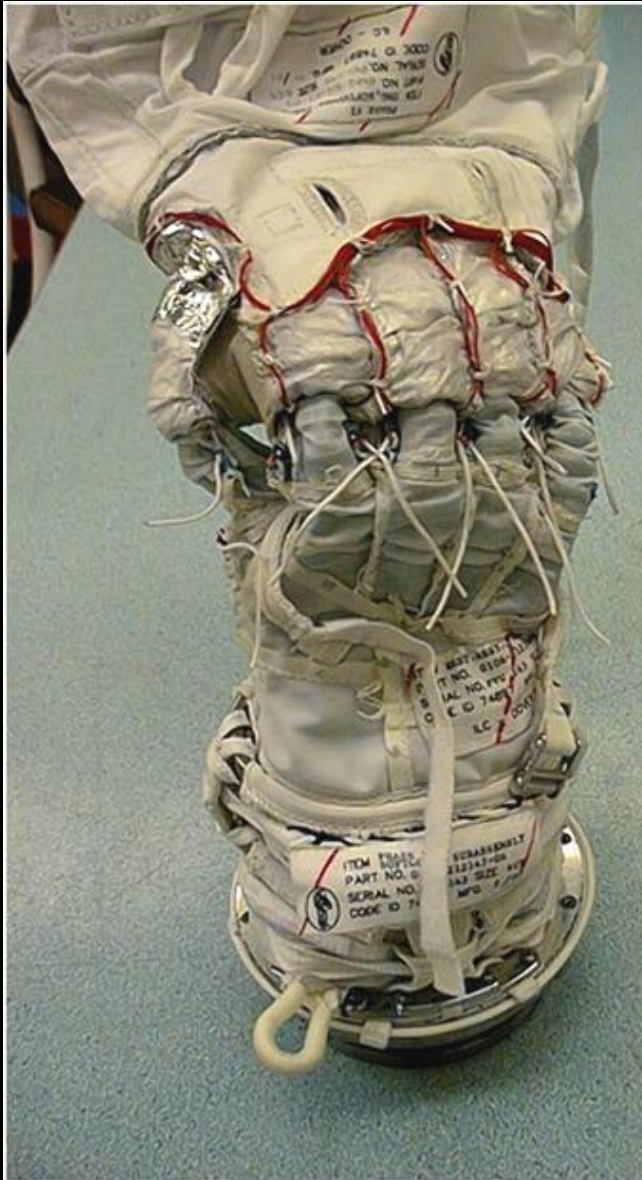
# EVA Systems - EMU



SOURCE: NASA



# EVA Systems – Space Suit Assembly Gloves & Boots

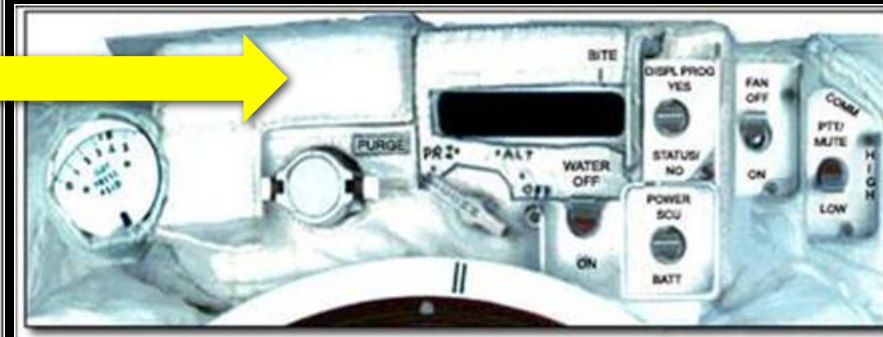
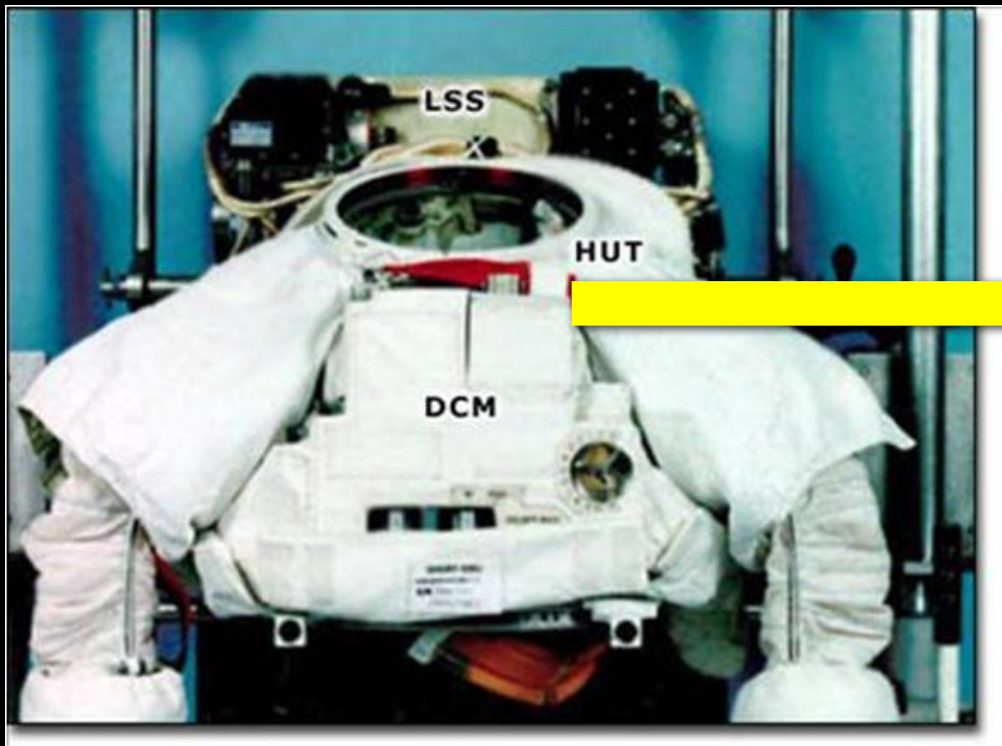




# EVA Systems – Life Support Upper Torso

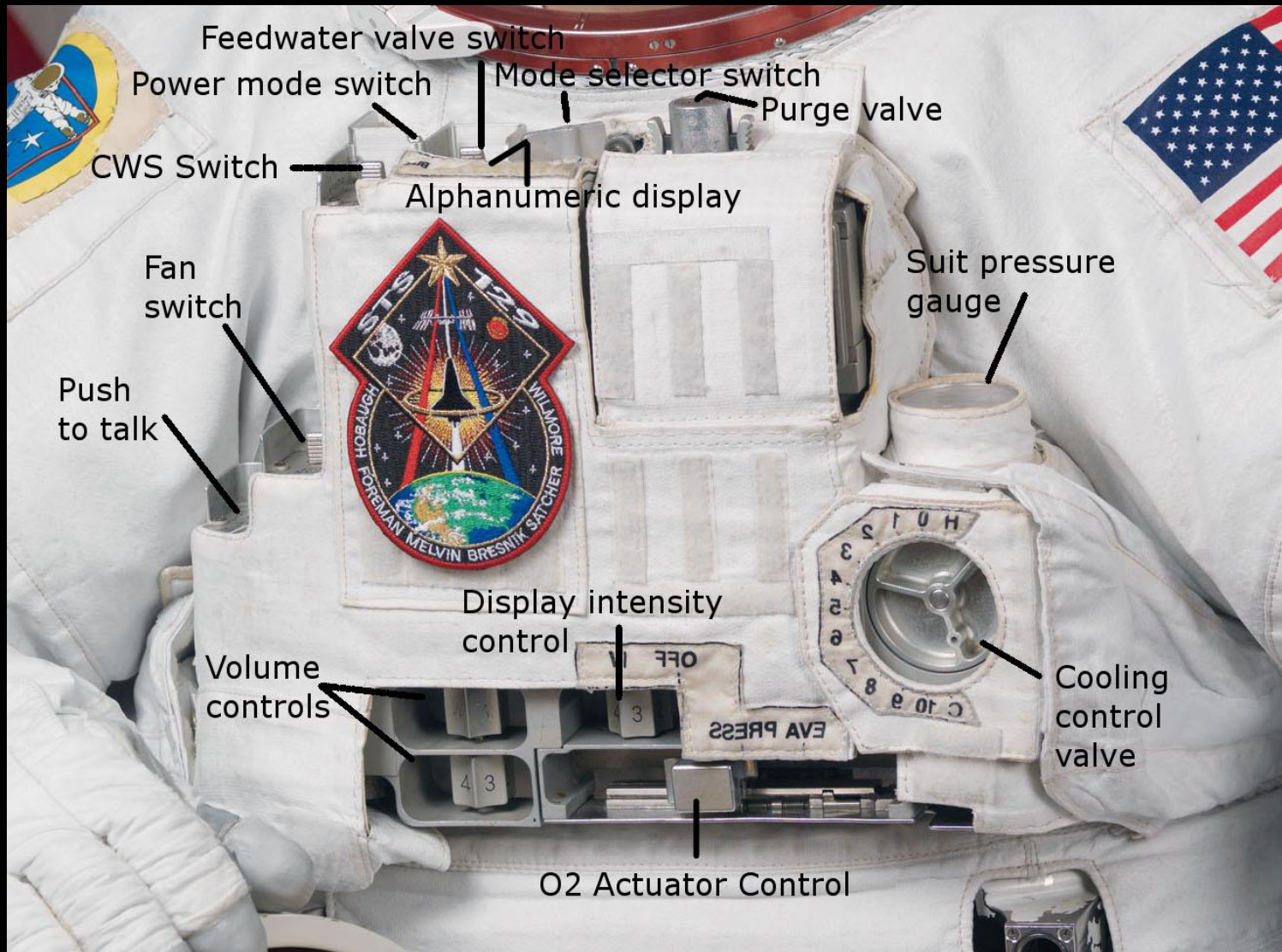


- Life Support System Components:
  - Display and Control Module (DCM)
    - Provides Caution & Warning System (CWS) messages, EMU parameters, and EMU controls to crewmember





# Display Control Module



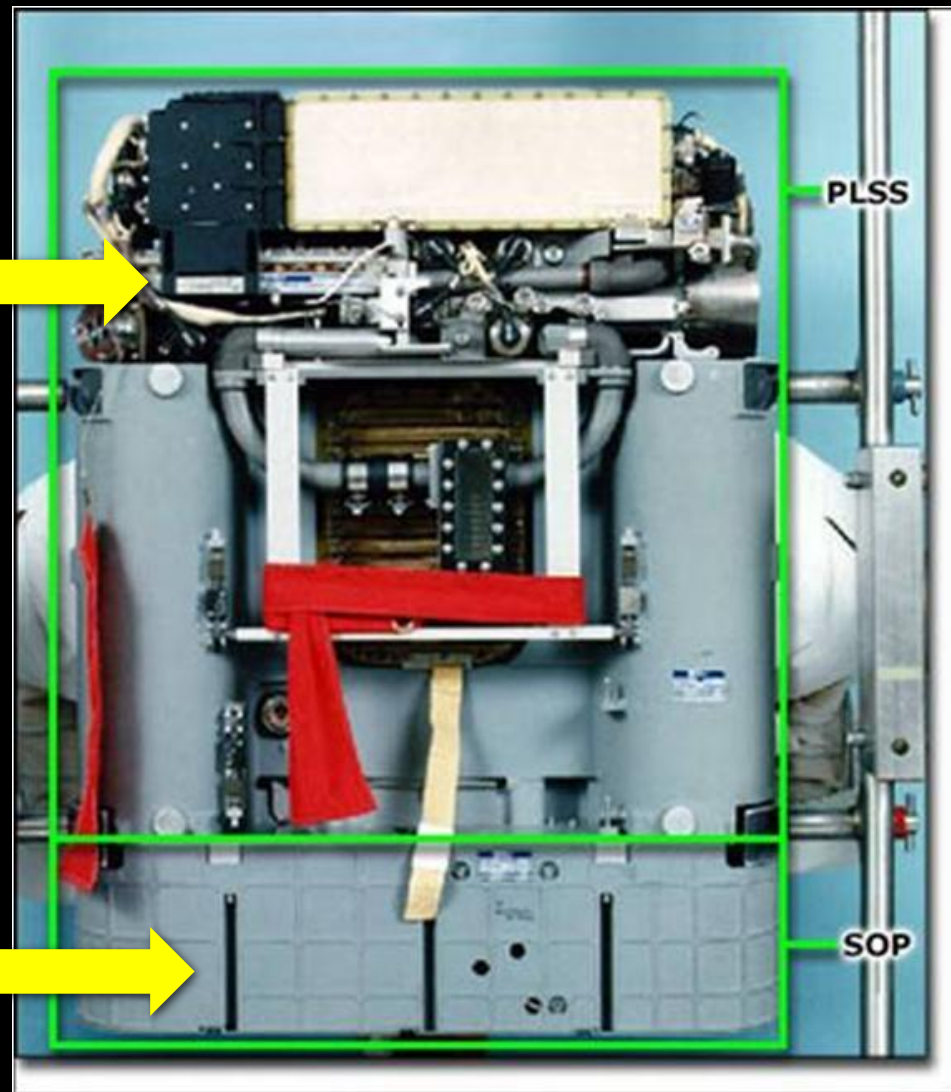


# EVA Systems – Life Support



- Life Support System Components:

- Portable Life Support Subsystem (PLSS)
  - Provides breathing  $O_2$ , electrical power, communications, cooling
  - Responsible for suit pressure control
  - Circulates  $O_2$  and removes  $CO_2$ , humidity and trace contaminants
  - Controls thermal environment
- Secondary Oxygen Package (SOP)
  - Provides a minimum of 30 minutes of emergency  $O_2$  in open-loop purge mode
  - Activated automatically during EVA, if necessary

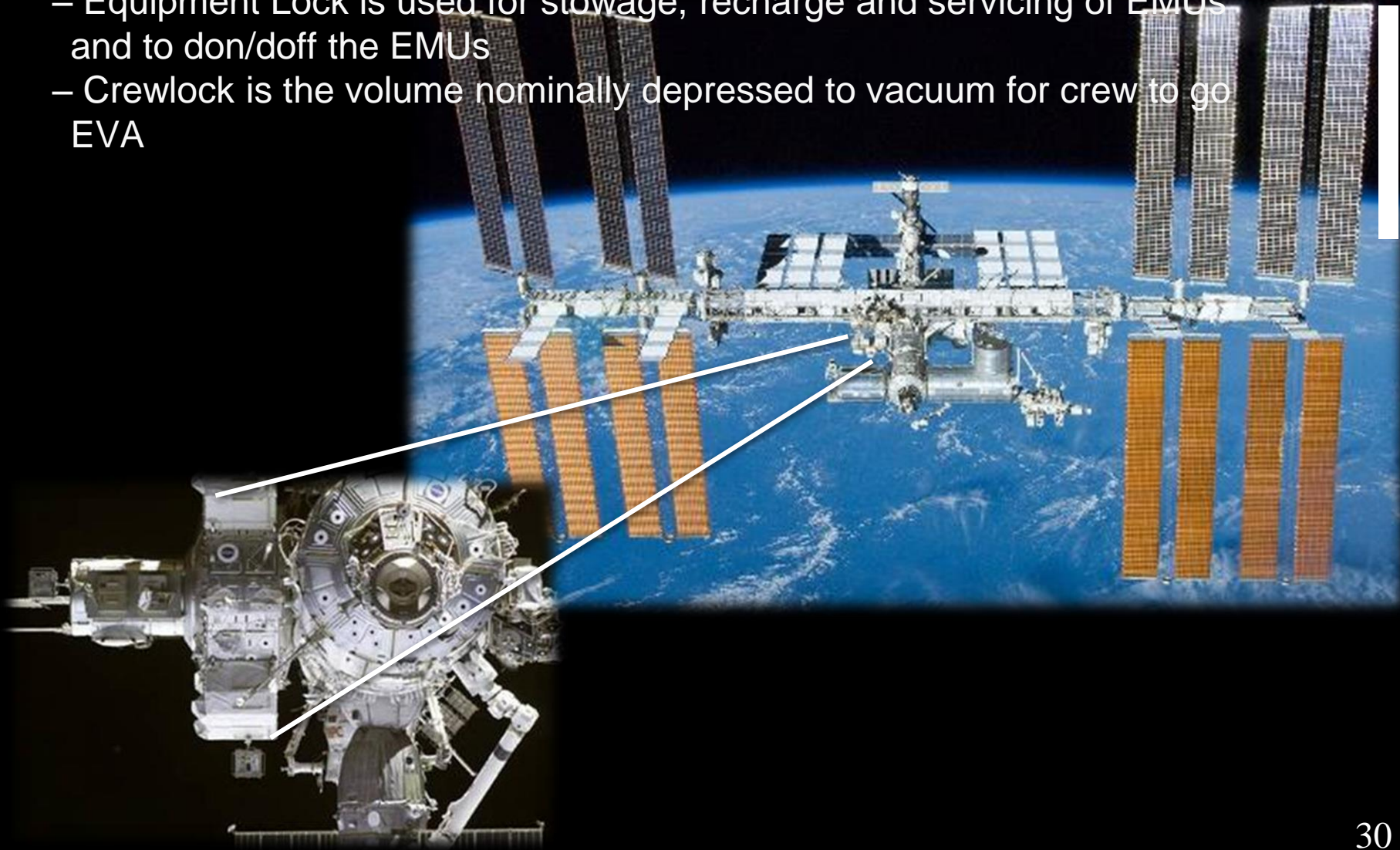




# EVA Systems - ISS Joint Airlock

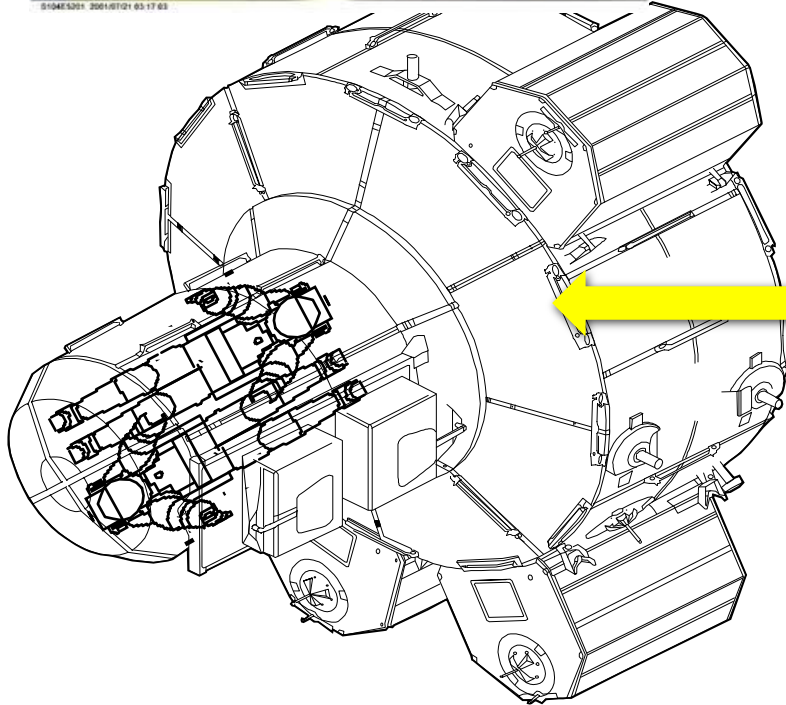
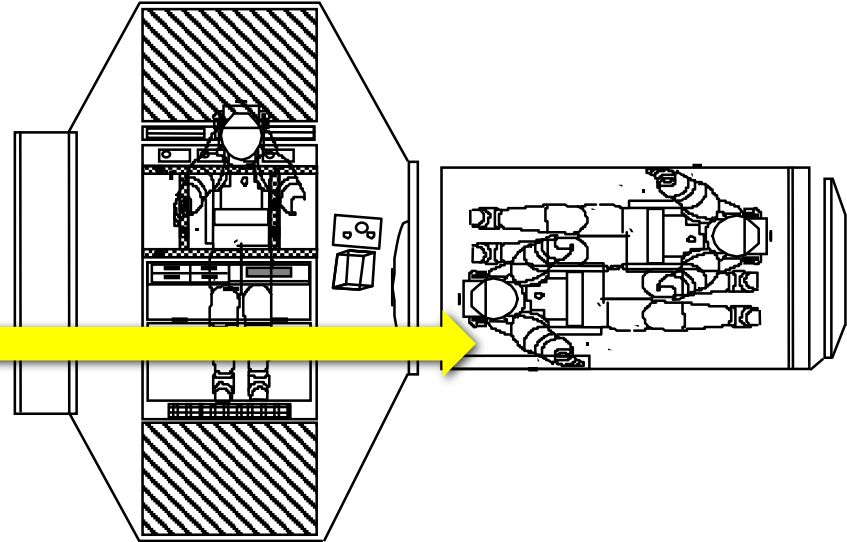


- ISS Joint Airlock:
  - Made up of two parts: Crew Lock and Equipment Lock
    - Equipment Lock is used for stowage, recharge and servicing of EMUs and to don/doff the EMUs
    - Crewlock is the volume nominally depressed to vacuum for crew to go EVA





# International Space Station (ISS) Joint Airlock





# EVA Equipment & Tools

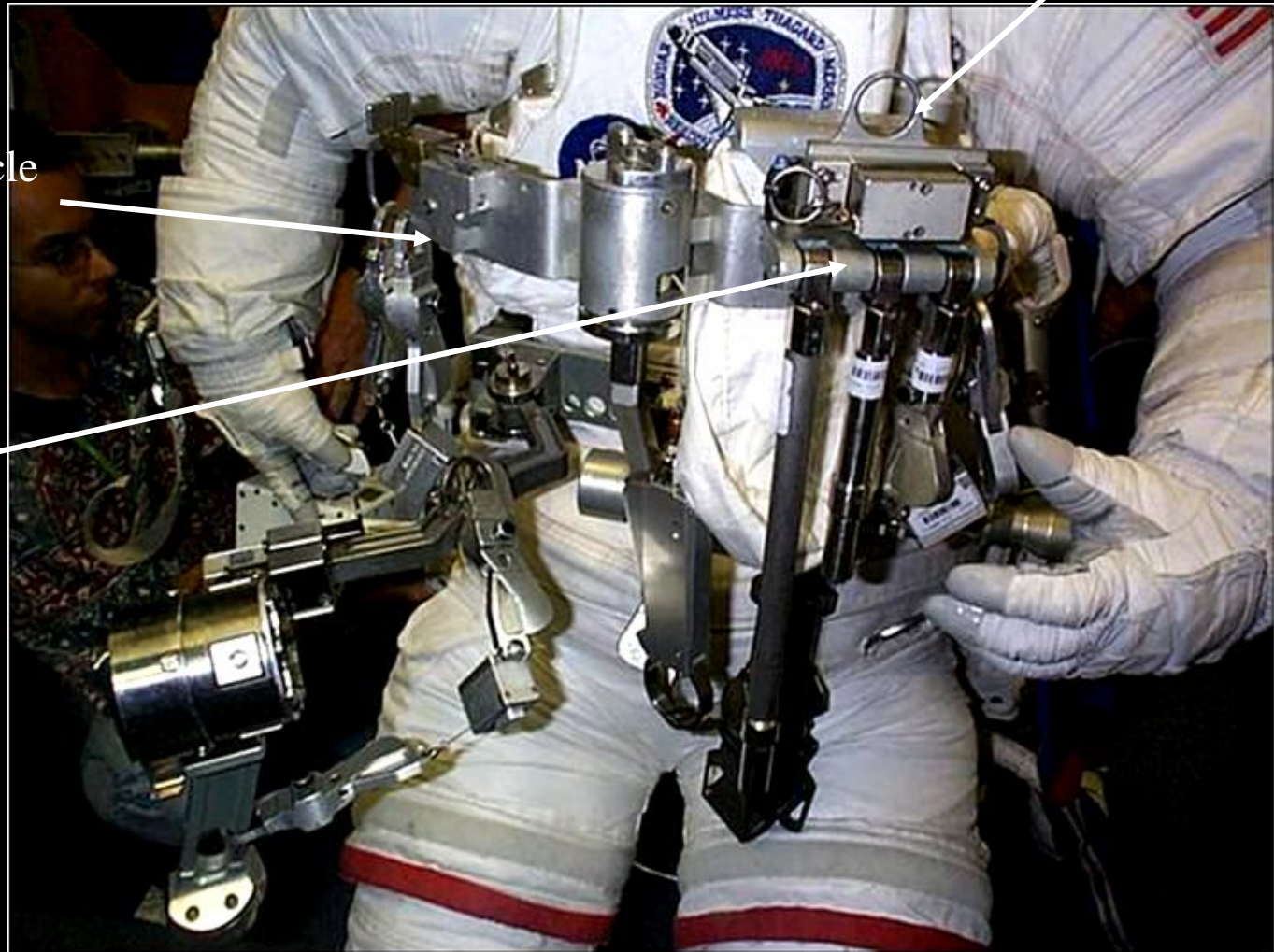


- Mini Work Station (MWS)
  - Attaches to front of the EMU
  - Used to carry small tools
  - Tools are secured via tether rings or via bayonet receptacles

Tether Loop

Bayonet Receptacle

Socket Caddy

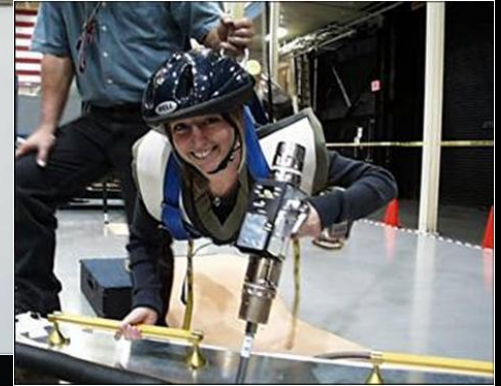




# EVA Equipment & Tools



- Pistol Grip Tool (PGT)
- Tethers



← 1-  
of

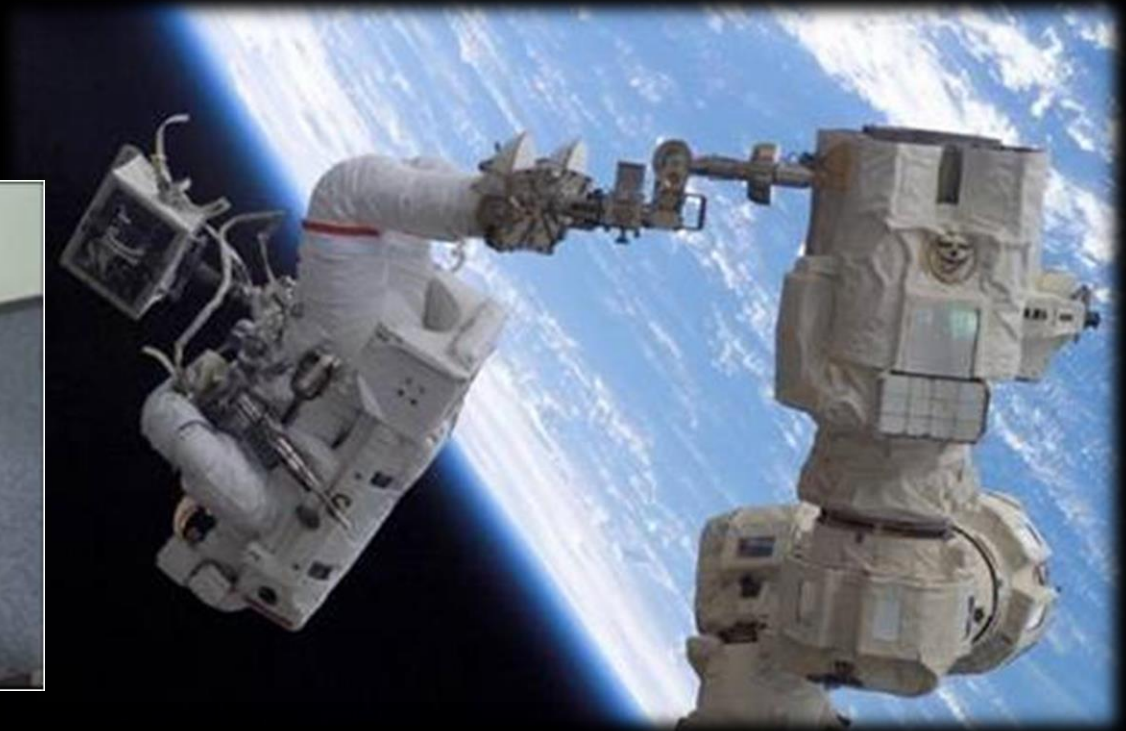




# EVA Equipment & Tools

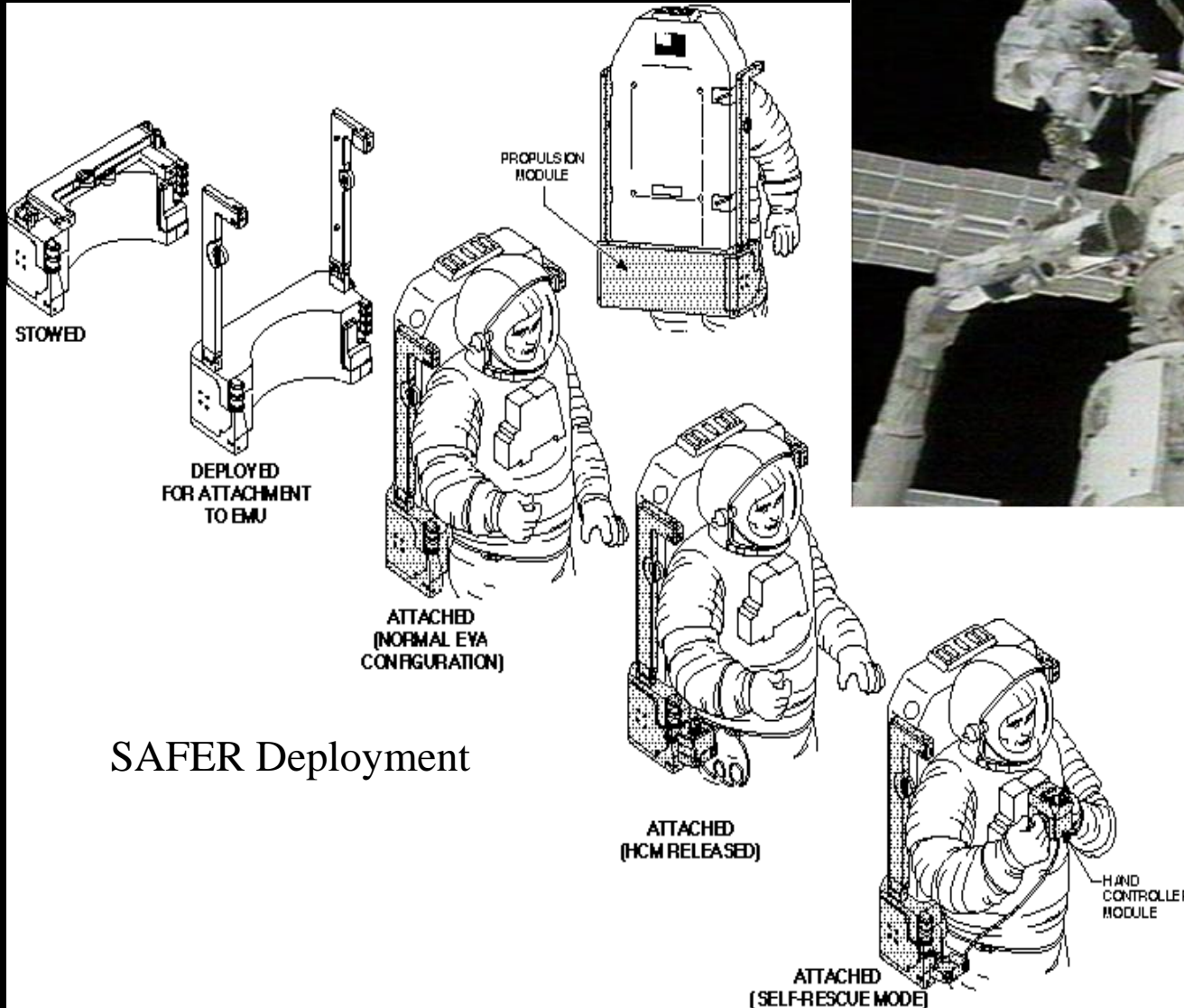


- Foot Restraints
  - Attach to structure via a socket
  - Provides EVA crewmember rigid restraint at a worksite (Newton's 3<sup>rd</sup> Law)
- Different types:
  - Articulating PFR (APFR) (*U.S. ISS*)
  - Interoperable APFR (IAPFR) (*U.S. & Russian ISS*)

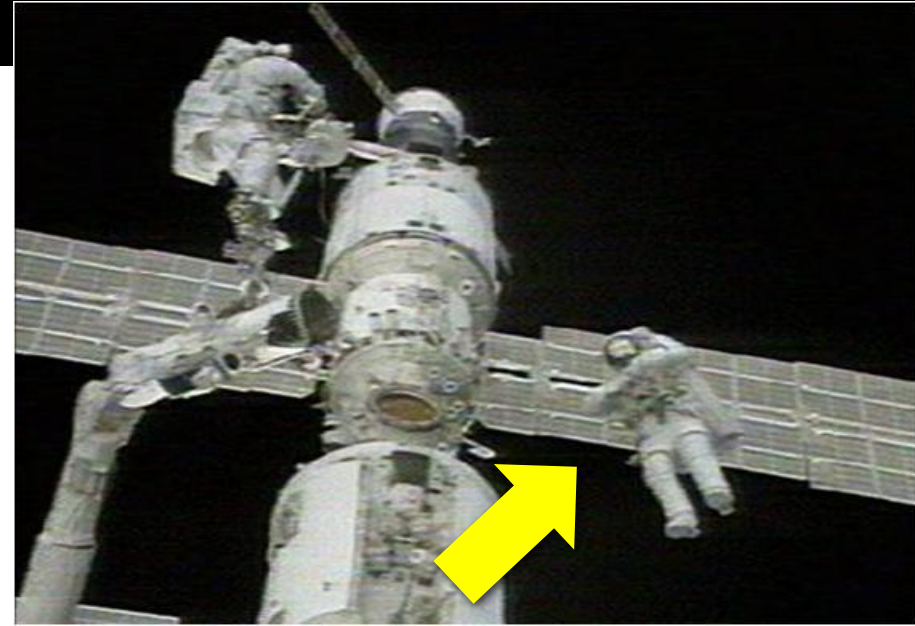




# EVA Systems - SAFER (Simplified Aid for EVA Rescue)

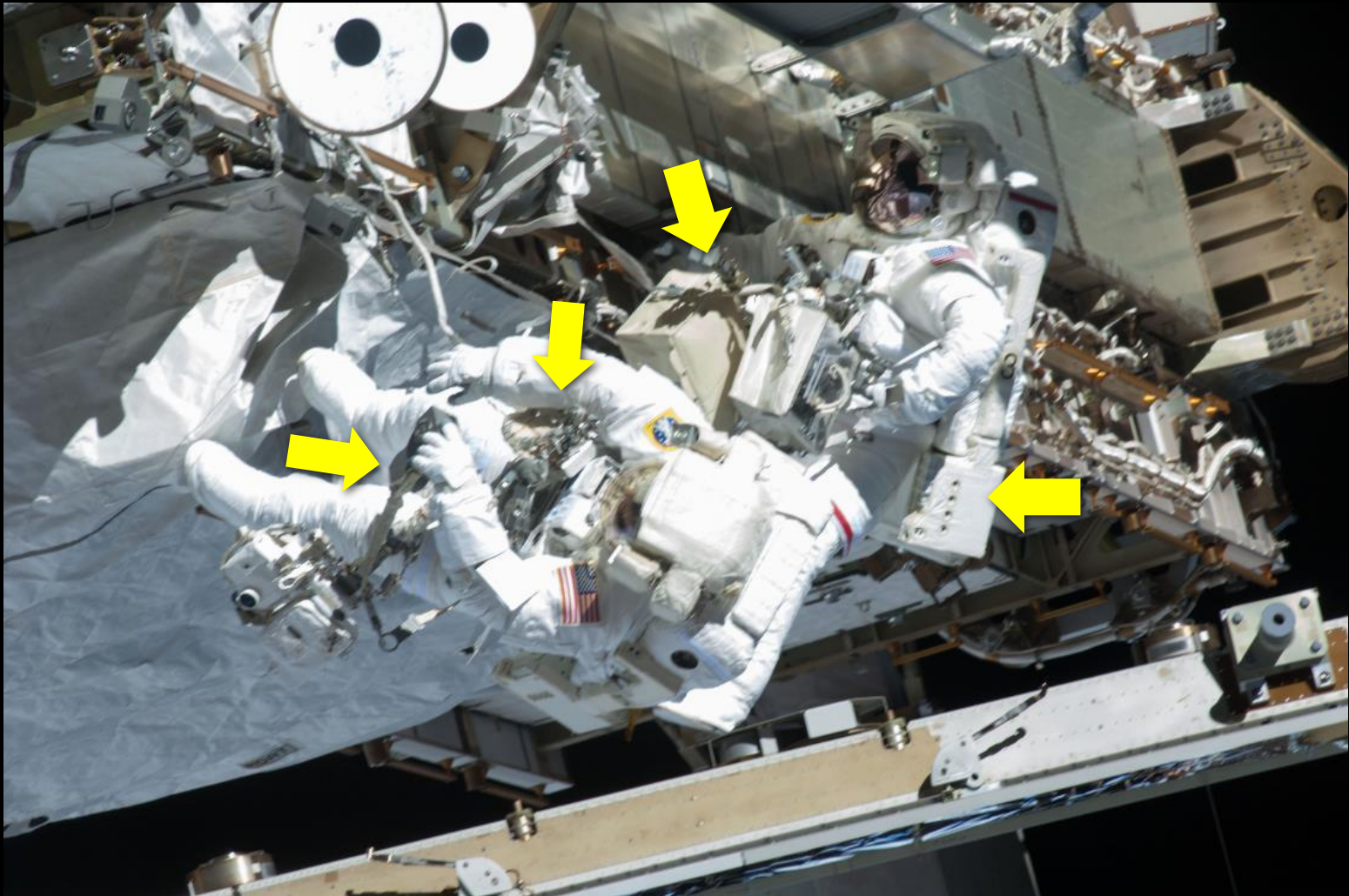


SAFER Deployment





# EVA Equipment & Tools





# What it looks like in “real-time”



Will show 0:00-2:00





# EVA Training Facilities

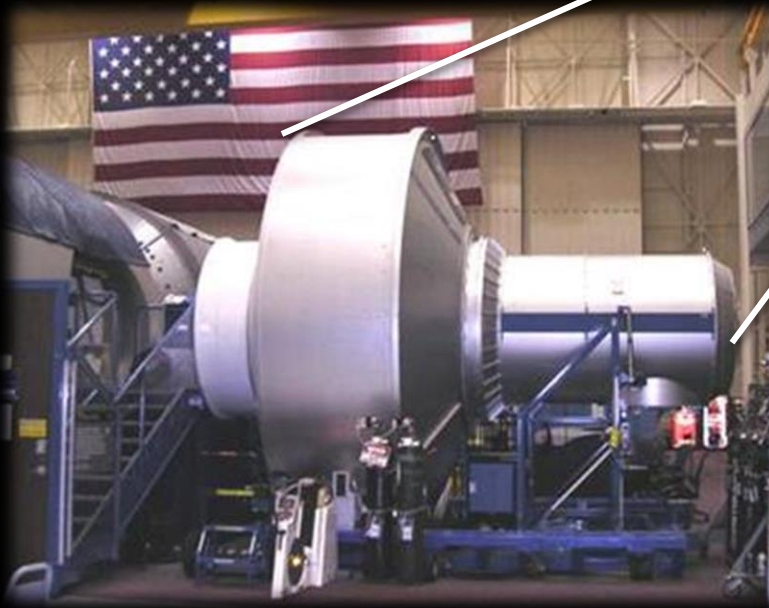
How do we train the Astronauts to safely complete spacewalks?



# EVA Training Facilities



- Space Vehicle Mockup Facility (SVMF) Airlock Mockup





# EVA Training Facilities



- EMU Caution and Warning System (ECWS) Trainer





# EVA Training Facilities



- Vacuum chambers
  - 11-foot chamber
  - Environmental Test Article (ETA) chamber
  - Space Environment Simulation Lab (SESL) chamber
  - Space Station Airlock Test Article (SSATA)

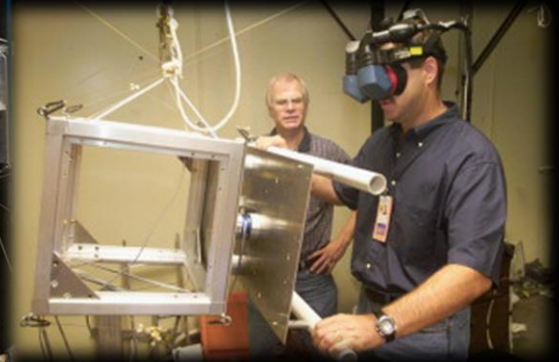
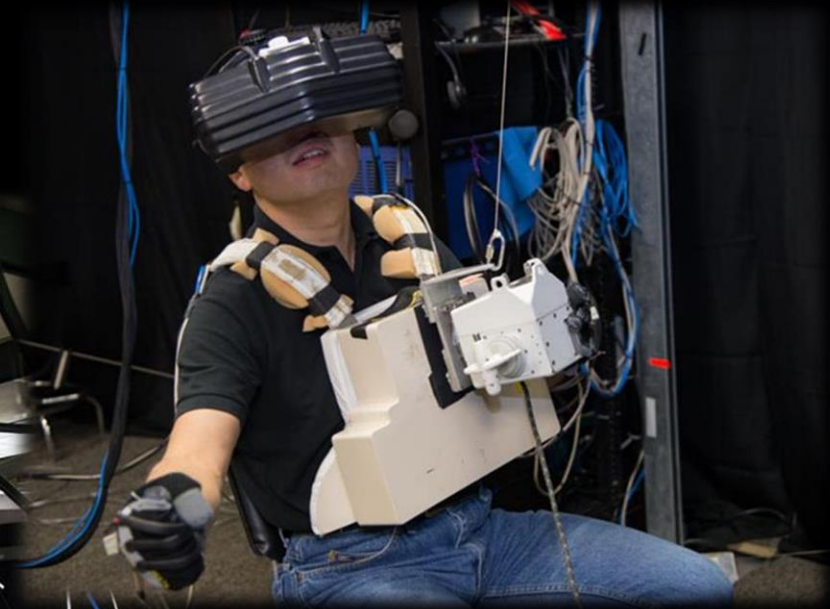




# EVA Training Facilities



- Virtual Reality Lab





# EVA Training Facilities



ARGOS - The Active Response Gravity Offload System



POGO



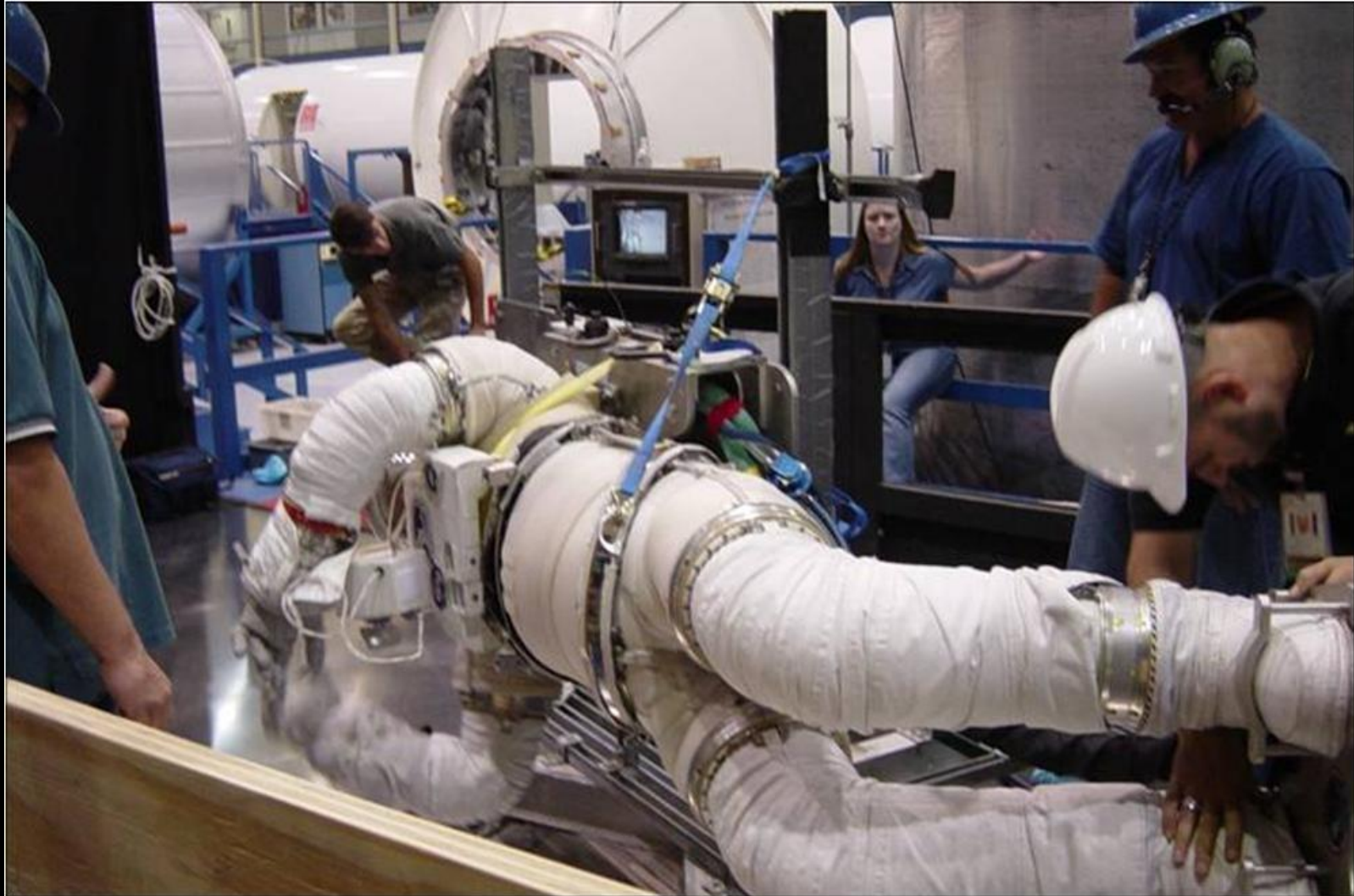
POGO/ARGOS uses an inline load cell to continuously offload a portion of a human or robotic subject's weight during all dynamic motions



# EVA Training Facilities



- Precision Air-Bearing Floor (PABF)

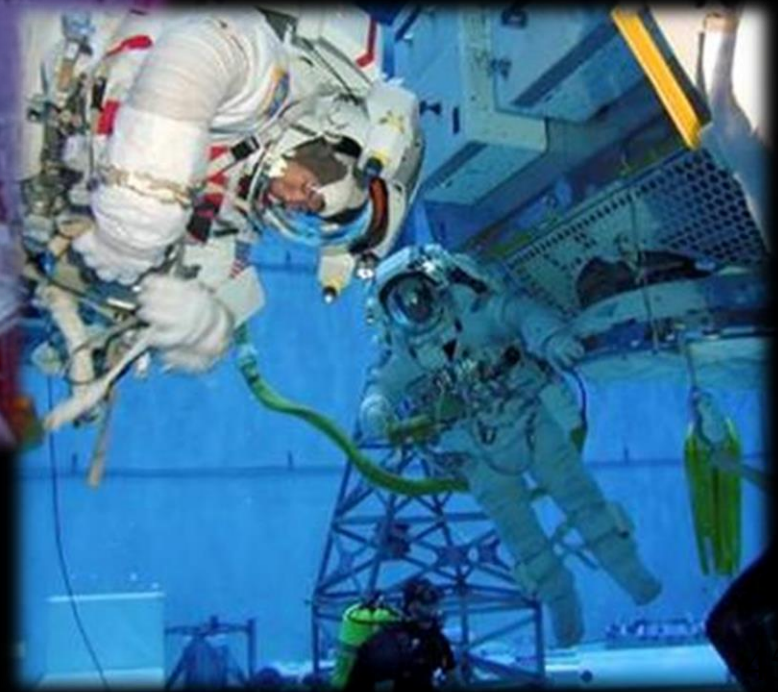




# EVA Training Facilities



- Neutral Buoyancy Laboratory (NBL)





# NBL Video



NBL training Will show video  
from 4:45 -6:30

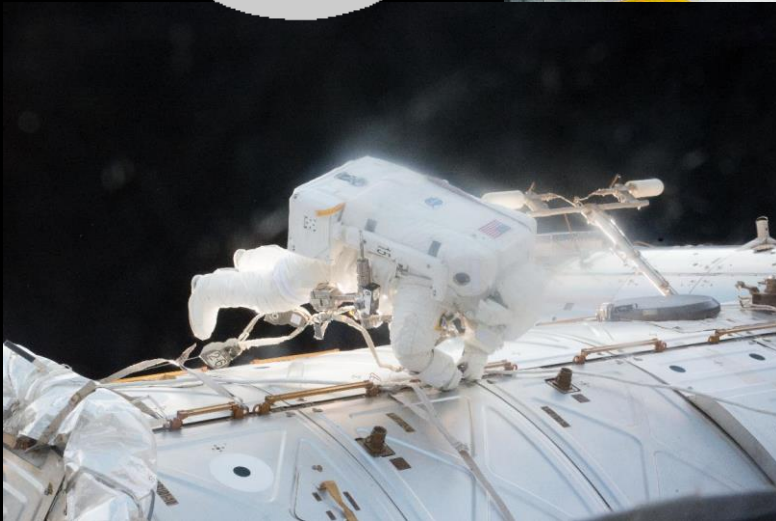
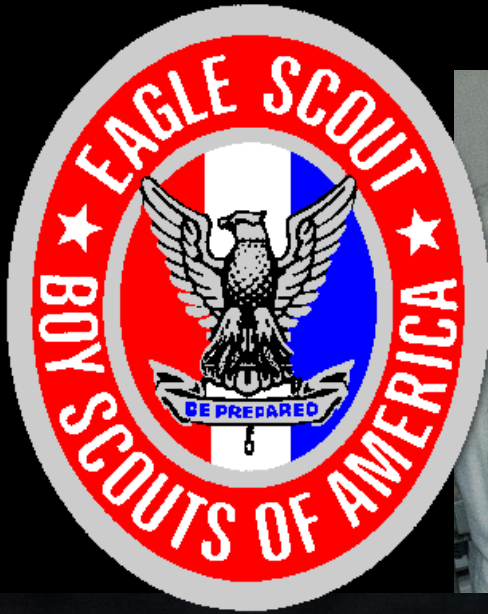




- Videos
- EVA 30 real-time
- <https://www.youtube.com/watch?v=26QWMMT1c8Y>
- NBL training
- <https://www.youtube.com/watch?v=6cwleHpAUE0>
- EVA 32 Kjell
- <https://www.youtube.com/watch?v=FWKW0qACcH0>
- EVA 32 timelapse
- <https://www.youtube.com/watch?v=yD9U89asG4o>
- EVA 33 timelapse
- <https://www.youtube.com/watch?v=VkcTcy1hrE4>



# Kjell Lindgren – Eagle Scout/Space Walker





# US EVA 32 Kjell Lindgren



Will show video from 0:00-2:00, then 6:40-8:40





# Human Deep Space Exploration

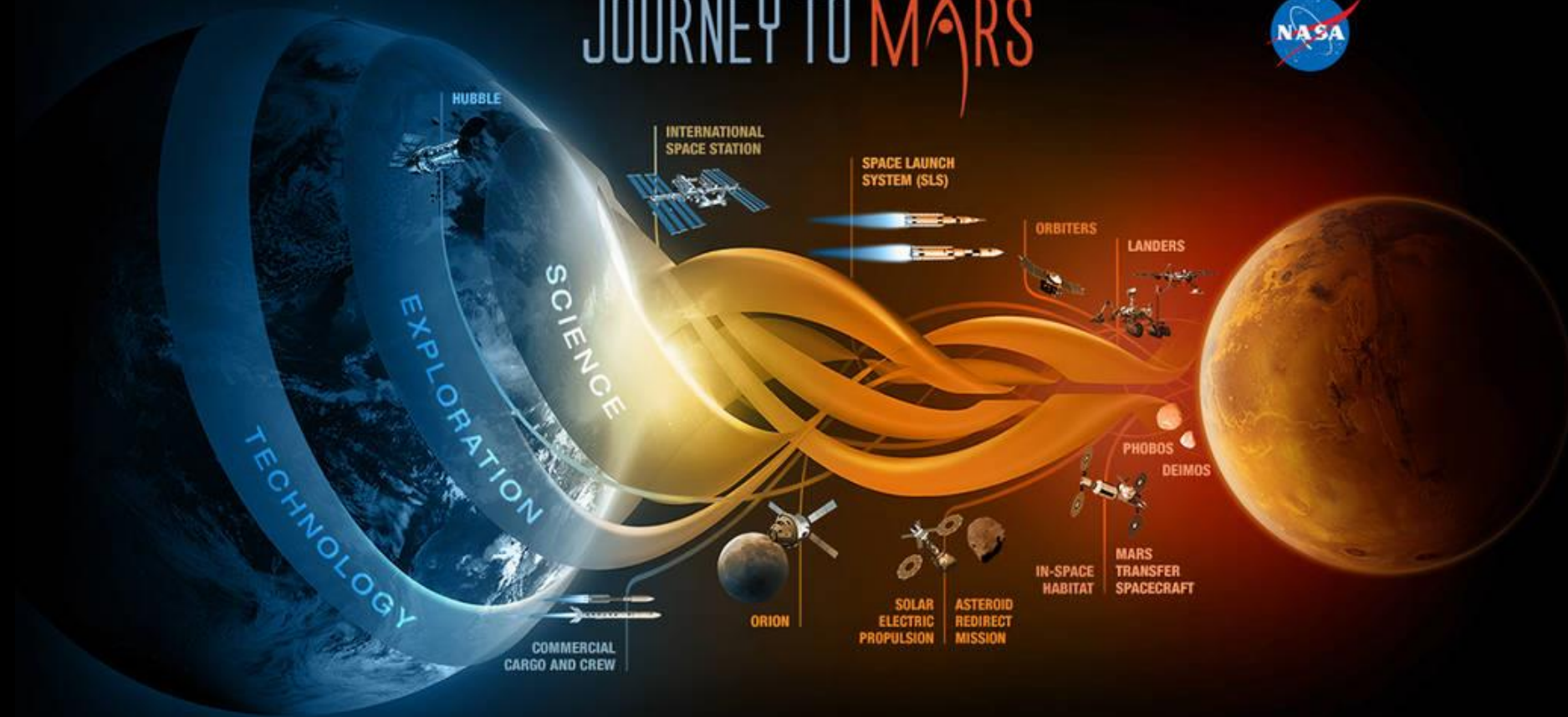
What are we doing now to prepare for a Journey to Mars?



# NASA Journey to Mars



## JOURNEY TO MARS





# MPCV – Multi-Purpose Crew Vehicle “Orion”

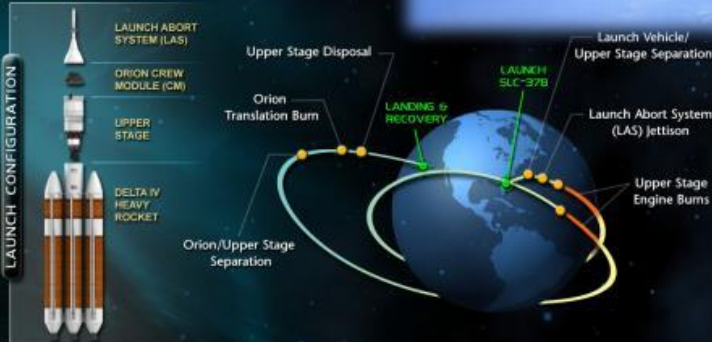


- First test flight completed in 2014
- Second test flight in 2018 (SLS)
- First Manned Mission 2021 (SLS)



## EXPLORATION FLIGHT TEST ORION

TWO ORBITS + 20,000 MPH ENTRY + 3,671 MILE APOGEE





# NASA Heavy Lift Vehicle - SLS



- SLS – Space Launch System
  - Estimated 80-120 metric tons capacity
  - First launch planned for 2018
- 5 Segment Solid rocket test this week



Cargo and Crew Vehicle



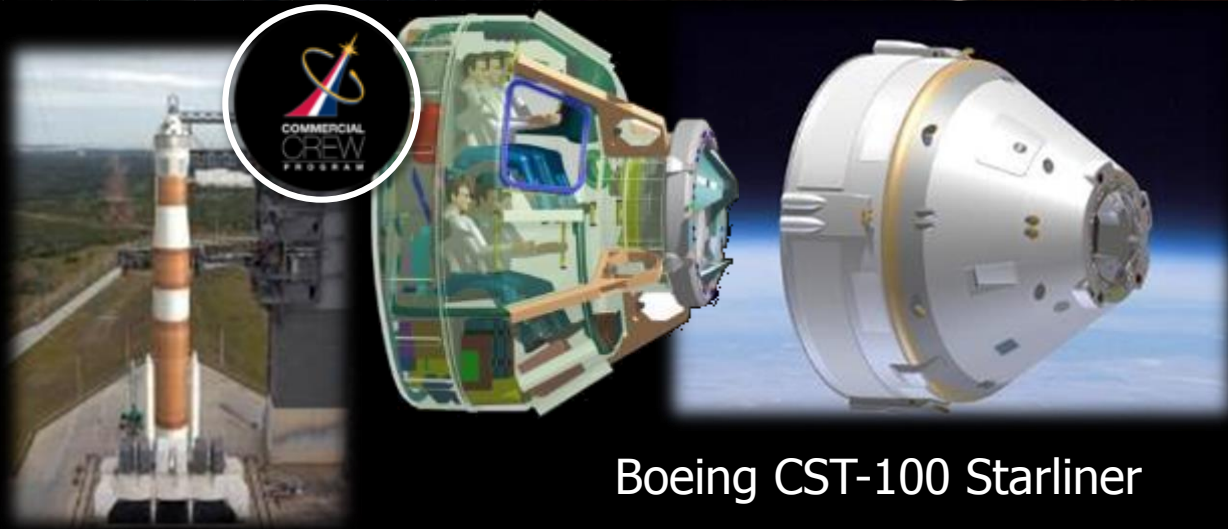


# Commercial Crew for LEO (Low Earth Orbit)



## 2 Companies

1. SpaceX Dragon 2
2. Boeing Starliner



Boeing CST-100 Starliner

SpaceX Dragon Capsule

Atlas V



Dragon Interior



Falcon 9 Rocket



# So, What is the Exploration plan?



- Develop strong commercial LEO presence
- Build the exploration vehicles for deep space missions
- Develop the technologies to support these deep space exploration
- Define the path to Mars



Orion



SLS

Deep Space Habitat

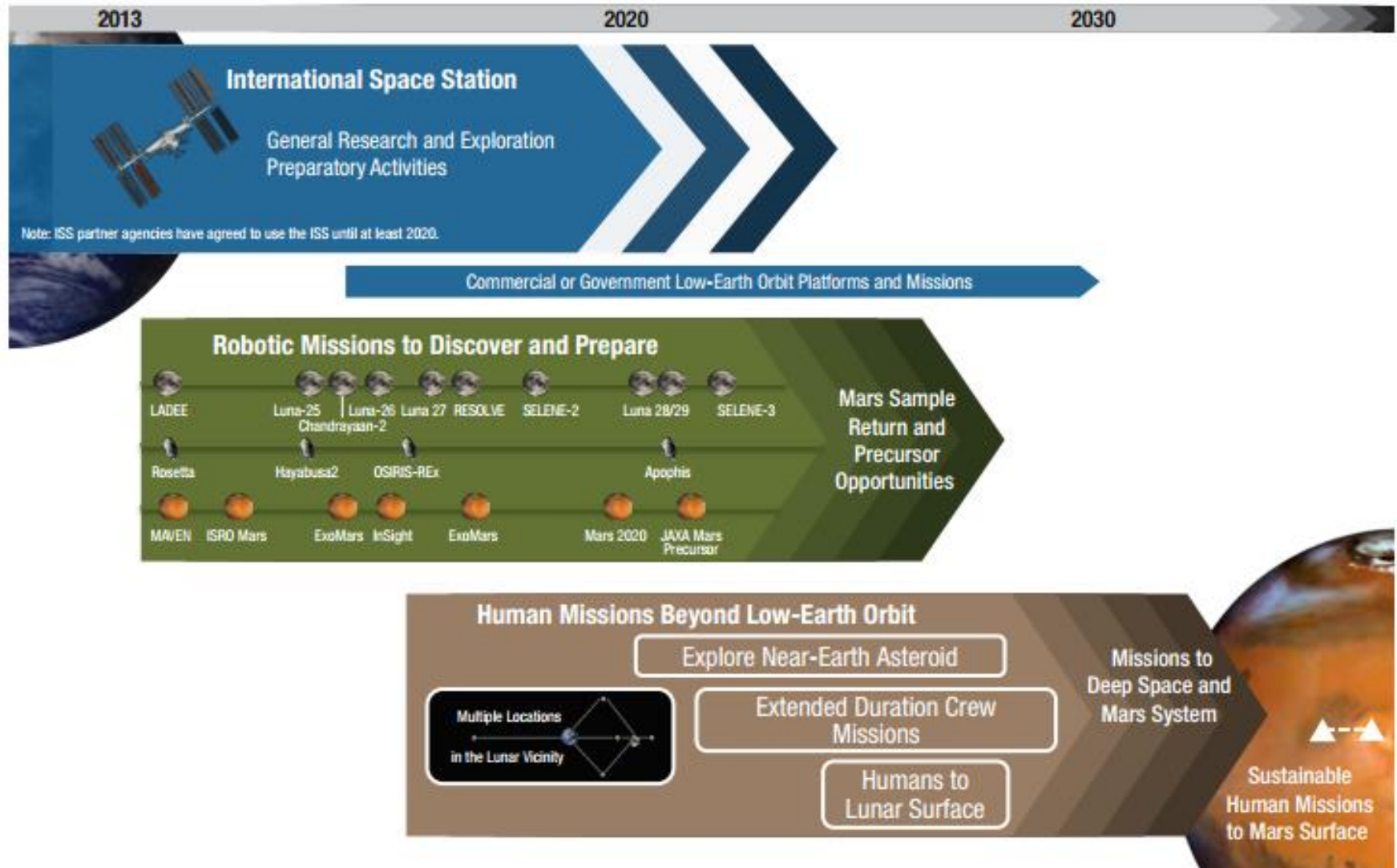




# Timing for all of these...



## Global Exploration Roadmap





8,000 miles

Low Earth Orbit (LEO)

250 miles

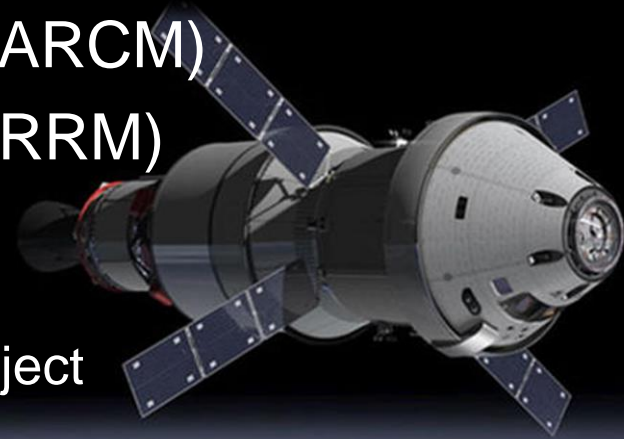
- Continue ISS through 2024 (2028?)
  - Focus on research and using as a test bed for exploration
- Engage commercial industry to service ISS
  - COTS (SpaceX and Orbital Sciences) – today
  - Commercial Crew - competitive programs – 2017?
    - CCDEv (1-2) – Commercial Crew Development
    - CCIcap- Commercial Crew Integration Capabilities
- Goal is to generate sustained commercial LEO industry



# Proposed Mission - Asteroid Redirect Mission



- Asteroid Redirect Return Mission (ARRM)
- Asteroid Redirect Crew Mission (ARRM)
  - Possible Lunar orbit or use of L2 (Lagrange point)
  - Science collection from deep space object
  - Exploration System Technology Demonstration

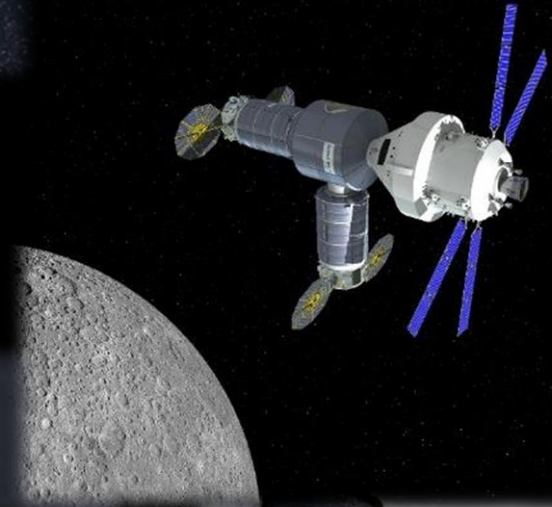




# Proposed Mission - Cise Lunar Missions



- Lunar orbiting outpost
  - Possible use of L2 (Lagrange point)
  - Science collection from deep space
  - Exploration System Technology Demonstration
- Lunar Base
  - Science collection
  - Exploration Systems Technology Demonstration
  - Surface Habitat, Lander and Walking suit test bed for Mars

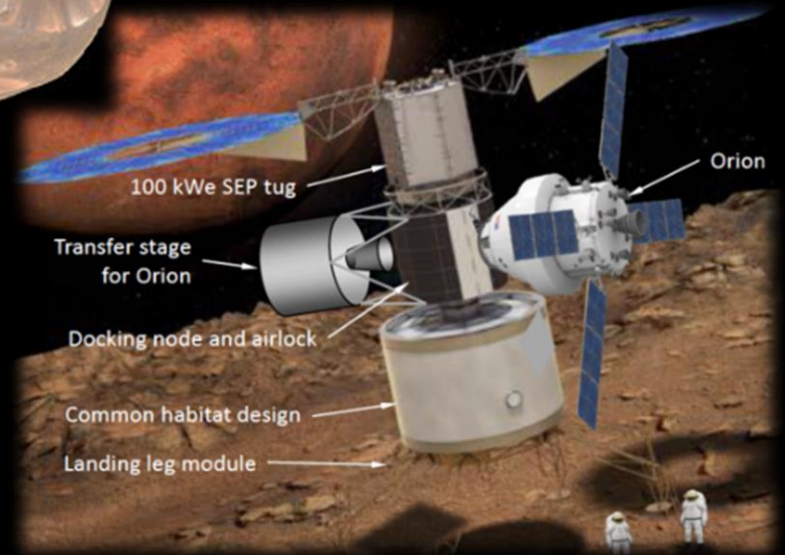
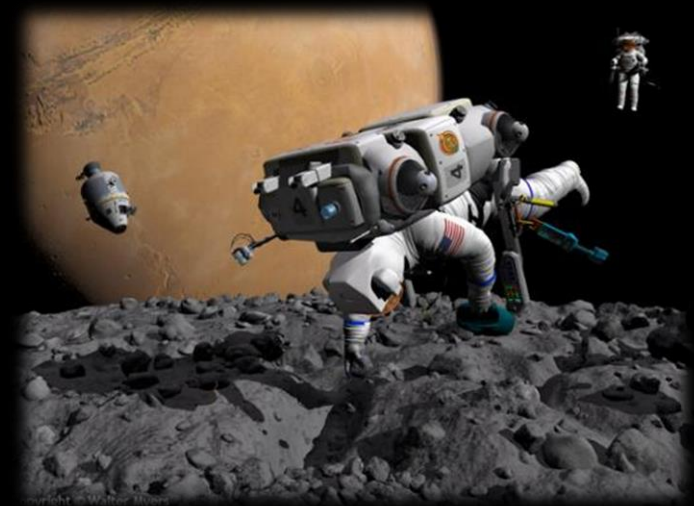




# Proposed Mission - Mars Orbital Mission- Phobos (Mars Moon)



- Possible first trip to Mars
- Technology gap not as big
- Proof of concept for long range mission
- More cost effective
- *Worth the trip??*





# Proposed Mission - Human Mars Mission



- 2-3 Year Mission
- Large technology gap exists
  - Both for Humans and Systems
- Large infrastructure required
- Will be International involvement
- Would be biggest risk, also biggest reward



Images Credit: The Martian/20<sup>th</sup> Century Fox



# Proposed Mission - Red Dragon



- Red Dragon is a proposed unmanned SpaceX Dragon capsule for low-cost Mars lander
- Missions to be launched using Falcon Heavy rocket(s)
- These Mars missions will also be pathfinders for the much larger SpaceX Mars colonization architecture that will be announced in September 2016
- Certain level of engagement with NASA via Space Act Agreement



SpaceX's Red Dragon Mars Mission in Images







# So what does it take to explore Deep Space?



# Space Exploration Challenges...



- Who would you need on a deep space mission?

## Standard for LEO today

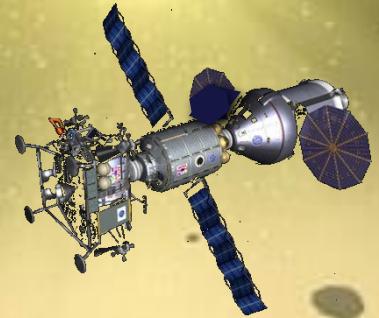
- Pilot
- Scientist
- Engineer

## Required Systems Experts for Exploration Missions

- Propulsion
- Navigation
- Communication
- Environmental (Plumber, AC, Heat)
- Power
- Stowage/Inventory

- Other crew, required?

- Doctor
- Dentist
- Psychologist
- Geologist
- Botanist
- IT/Computer Expert
- Machinist
- Handyman
- Sheriff
- Judge/Lawyer



**20+**  
**People???**



# Space Exploration Challenges...



- Up mass
  - Exploration Vehicle – est. 100 tons of material and supplies (ISS 420 tons)
- Propulsion
  - Chemical, Ion, Solar Electric
- Environmental Systems
  - Closed loop, Reliability, Redundancy
- Automation
  - Self maintaining systems
- Radiation Shielding
  - Crew and systems health
- Communication
  - Comm delays increase
- Long Range Human Health Affects
  - Bone health, eye damage, long term radiation exposure
- Stowage/Logistics



# Next Extraterrestrial Footprints – 2030?



- We left a lot of Human footprints on the moon...

Who will make that  
first human foot  
print on Mars?





# Next Extraterrestrial Footprints – 2030?



Could be one of you!!



Yes You!  
So come join us!!



# Thank You!







# My favorites...



# My favorite sites and links...



- Heavens Above
  - <http://heavens-above.com/>
- NASA Spinoffs
  - <http://spinoff.nasa.gov/>
- Eyes on the Solar System
  - <http://eyes.nasa.gov/>
  - Youtube NASA Television
    - <http://www.youtube.com/user/NASAtlevision>
  - Youtube Earth Video
    - <http://www.youtube.com/watch?v=lp2ZGND1I9Q>
  - ISS Tour by CDR/Suni Williams
    - <http://www.youtube.com/watch?v=doN4t5NkW-k>
  - Why Mars is Hard Stan Love
    - <http://www.youtube.com/watch?v=fturU0u5KJo>
- Perspectives
  - <http://htwins.net/scale2/?bordercolor=white>
- ISSLive
  - <http://spacestationlive.jsc.nasa.gov/>
- Distance Learning Network
  - NASA DLN Website: <http://www.nasa.gov/offices/education/programs/national/dln/index.html>
  - Toolkit with Material and Templates:  
<http://communications.nasa.gov/OCP/Communications%20Tool%20Kit/Presentation%20Template%20Web%20Site/CTK.html>





# JPL – Eyes on the Solar System



Eyes on the Solar System

<http://eyes.nasa.gov/>



<http://htwins.net/scale2/?bordercolor=white>

## Giant Earthworm



10<sup>0.0</sup>

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Other languages

Back

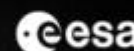
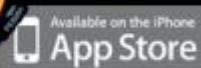


# ISSLive



ISSLive

<http://isslive.com/>





# Youtube – REELNASA



## ReelNASA

[http://www.youtube.com/results?search\\_query=reelnasa&sa=X&spell=1&search=Search&oi=spell](http://www.youtube.com/results?search_query=reelnasa&sa=X&spell=1&search=Search&oi=spell)

A screenshot of a YouTube search results page. The search bar at the top contains the text "reelnasa". Below the search bar, there are filter options and a note that says "About 990 results". The main content area displays a list of video results. The first result is from the "Reel NASA" channel, with a video titled "Science off the Sphere: Knitting Needle Experiment". The second result is also from "Reel NASA", titled "We Are the Explorers". The third result is from "Reel NASA", titled "Chase Plane Video Of Historic SpaceX Splashdown". The fourth result is from "Reel NASA", titled "Science off the Sphere: Gool". Each result includes a thumbnail image, the video title, a brief description, and the number of views. The "Reel NASA" channel name is also visible at the top of the first result.

**You Tube** reelnasa Browse | Mov

Filter ▾ About 990 results

**Reel NASA**  
Get off my planet. Give me my space. Get real with **Reel NASA**. Space trav ...  
ISS Update: Dr. Steve Squyres, NEEMO 16 Aquanaut and Cornell Professor  
CHANNEL by ReelNASA | 928 videos | 31,508 subscribers

**Science off the Sphere: Knitting Needle Experiment**  
challenge and view future experiments here: www.physicscentral.com ... **Reel NASA** ...  
"Science off the Sphere" "American Physical Society" "Don Pettit" ...  
CC by ReelNASA | 4 months ago | 546,686 views

**We Are the Explorers**  
is helping us lay the foundation for our greatest journeys ahead. ... **Reel NASA** ... NASA  
exploration "Peter Cullen" space flew shuttle station Orion ...  
HD CC by ReelNASA | 3 months ago | 176,084 views

**Chase Plane Video Of Historic SpaceX Splashdown**  
berth with the International Space Station, paving the way for future commercial cargo delivery  
flights. ... **Reel NASA** ... 120601 SpaceX ...  
HD by ReelNASA | 3 weeks ago | 70,754 views

**Science off the Sphere: Gool**  
challenge and view future experiments here: www.physicscentral.com ... **Reel NASA** ...  
"international space station" "expedition 31" "don pettit" ...  
CC by ReelNASA | 1 month ago | 8,412 views

**Interview with NASA Earth Scientist Melissa Davares**



# NASA Spinoffs



<http://spinoff.nasa.gov/>



**Office of the Chief Technologist**  
Value for NASA, Benefits for the Nation  
**NASA Spinoff**



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Jeopardy! host Alex Trebek shares how NASA spinoffs provide tangible benefits for the Nation.

**NASA @ Home and City**



Find a trace of outer space in your home and city.

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**Spinoff Tweets**



NASA Spinoff

**NASASpinoff**



# Heavens Above



<http://heavens-above.com/>

Heavens-Above Home Page - Windows Internet Explorer

Address bar: <http://heavens-above.com/>

File Edit View Favorites Tools Help

HomeDO4 Flight Planning Br... wVU engineering - Bing HomeDO4 Flight Planning Br...

Heavens-Above Home Page x ISSLive! Bringing the Interna...

Find: biconic Previous Next Options

 [Aerospace](#)  
Earn an Aerospace degree online at American Public University System.  
[www.APUS.edu/Aerospace](http://www.APUS.edu/Aerospace) AdChoices

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### Configuration

Current observing site: **Clear Lake, 33.0781°N, 96.4950°W**  
[select from map](#) or [from database](#) or [edit manually](#)  
[Registered user login](#) | [Why register?](#)  
[Create new user account](#)

### Satellites

10 day predictions for: [ISS](#) | [Tiangong 1](#)  
[Genesis-1 / 2](#) | [Envisat](#) | [HST](#)  
[Select another satellite](#) from the database  
Daily predictions for all satellites brighter than magnitude:  
(brightest) 3.5 | 4.0 | 4.5 (dimmiest)  
All passes of [ISS](#) - including daylight and invisible passes.  
Iridium Flares  
[next 24 hrs](#) | [next 7 days](#) | [previous 48 hrs](#)  
Daytime flares for 7 days - see satellites in broad daylight!  
[Spacecraft escaping the Solar System](#) - where are they now?  
[Radio amateur satellites](#) - 24 hour predictions (all passes)  
[Height of the ISS](#) | [Phobos Grunt](#) - how does it vary with time

### Astronomy

Comets currently brighter than mag. 12  
[189P NEAT](#) | [96P Machholz](#) | [C/2009 P1 Garradd](#)  
Minor planets currently brighter than mag. 10  
[4 Vesta](#) | [1 Ceres](#) | [18 Melpomene](#)  
[Whole sky chart](#)  
[Sun and Moon data for today](#)  
[Planet summary data](#)  
[Planet details \(under construction\)](#)  
[Mercury](#) | [Venus](#) | [Earth](#) | [Mars](#) | [Jupiter](#) | [Saturn](#) | [Uranus](#) | [Neptune](#) | [Pluto](#)  
[Solar system chart](#)



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Current position of ISS

 523

### GPS Fleet Tracking

GPS Tracking Lowers Costs Free, Live Demonstration  
[www.Saoe-Quest.com](http://www.Saoe-Quest.com)


start | 7 Microsoft... | 2 Windows... | 3 Microsoft... | 4 Internet ... | Intel® PROS... | 2 Microsoft... | Desktop | 12:24 PM



# NASA Distance Learning



NASA DLN Website: <http://www.nasa.gov/offices/education/programs/national/dln/index.html>



HOMENEWSMISSIONSMULTIMEDIACONNECTABOUT NASA

Search

NASA Home > Education > Programs > DLN

SendShare

Digital Learning Network (DLN)

DLN Home

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Event Catalog

PD & Special Events

Event Guidelines

DLInfo Channel

Technical FAQ


5E Teaching Model

Tools & Plugins

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Feedback Forms

Search Event




NASA Digital Learning Network™


DLN sites: Ames, Dryden, Glenn, Goddard, JPL, Johnson, Kennedy, Langley, Marshall, Stennis

A Universe of Possibilities

Welcome to NASA's DLN


NASA's Digital Learning Network™ provides science, technology, engineering, and mathematics or STEM content featuring NASA missions and research. Register for free, interactive events listed in our catalog or watch our webcasts listed below.

 Like us on Facebook!

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To assist both new and existing users, we **STRONGLY** encourage you to view our DLN Overview Video and the DLIntro presentation located in [About DLN](#). DLIntro will guide you through our website, show how to register for modules, and explain other services.

DLN Announcements



DLN User

> Sign In

> New User Registration

> New School/Org Registration

> Forgot Password

USDLA Awards NASA's Digital Learning



# NASA Exploration Technologies



**High-Efficiency Space Power Systems:** This project develops technologies to provide low-cost, abundant power for deep-space missions, including advanced batteries and regenerative fuel cells for energy storage, power management and distribution, solar power generation, and nuclear power systems. A major focus will be on the demonstration of dual-use technologies for clean and renewable energy for terrestrial applications.



**Human Robotic Systems:** This project develops advanced robotics technology to amplify human productivity and reduce mission risk by improving the effectiveness of human-robot teams. Key technologies include teleoperation, human-robot interaction, robotic assistance, and surface mobility systems for low-gravity environments. Early demonstrations will focus on human teams interacting with multiple robotic systems. Longer-term demonstrations will focus on enabling operations in remote, hostile environments with limited support from Earth.

› [About Robonaut, NASA's dexterous humanoid robot](#)



**In-Situ Resource Utilization:** This project will enable sustainable human exploration by using local resources. Research activities are aimed at using lunar, asteroid, and Martian materials to produce oxygen and extract water from ice reservoirs. A flight experiment to demonstrate lunar resource prospecting, characterization, and extraction will be considered for testing on a future robotic precursor exploration mission. Concepts to produce fuel, oxygen, and water from the Martian atmosphere and from subsurface ice will also be explored.

› [About in-situ resource utilization \(ISRU\) field testing in Mauna Kea, Hawaii](#)



**Life Support and Habitation Systems:** This project develops technologies for highly reliable, closed-loop life support systems, radiation protection technology, environmental monitoring and control technologies, and technologies for fire safety to enable humans to live for long periods in deep-space environments.



**Lightweight Spacecraft Materials and Structures:** This project develops advanced materials and structures technology to enable lightweight systems to reduce mission cost. Technology development activities focus on structural concepts and manufacturing processes for large composite structures and cryogenic propellant tanks for heavy lift launch vehicles, and on fabric materials and structural concepts for inflatable habitats.

<http://www.nasa.gov/exploration/technology/>



# NASA Exploration Technologies



**Advanced In-Space Propulsion:** This project develops concepts, technologies, and test methods for high-power electric propulsion and nuclear thermal propulsion systems to enable low-cost and rapid transport of cargo and crew beyond low Earth orbit.



**Autonomous Systems and Avionics:** This project develops and demonstrates integrated autonomous systems capable of managing complex operations in space to reduce crew workload and dependence on support from Earth. Technologies will address operations in extreme environments, efficient ground-based and on-board avionics systems and operations, and cost-effective human-rated software development.



**Cryogenic Propellant Storage and Transfer:** This project develops technologies to enable long-duration storage and in-space transfer of cryogenic propellants. Technology development includes active cooling of propellant tanks, advanced thermal insulation, measurement of propellant mass, liquid acquisition devices, and automated fluid couplings for propellant transfer between vehicles.



**Entry, Descent, and Landing (EDL) Technology:** This project develops advanced thermal protection system materials, aerothermodynamics modeling and analysis tools, and concepts for aerocapture and atmospheric entry systems for landing large payloads safely and precisely on extra-terrestrial surfaces and returning to Earth.

› [Read about the Mars Science Laboratory Entry, Descent, and Landing Instrument \(MEDLI\) Suite](#)



**Extravehicular Activity Technology:** This project develops component technologies for advanced space suits to enable humans to conduct "hands-on" surface exploration and in-space operations outside habitats and vehicles. Technology development includes portable life support systems, thermal control, power systems, communications, avionics, and information systems, and space suit materials.

<http://www.nasa.gov/exploration/technology/>



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- [spaceflight.nasa.gov/realdata/sightings](https://spaceflight.nasa.gov/realdata/sightings)

SATELLITE	LOCAL DATE/TIME	DURATION (MIN)	MAX ELEV (DEG)	APPROACH (DEG-DIR)	DEPARTURE (DEG-DIR)
ISS	Tue Nov 14/06:22 AM	4	66	10 above WSW	31 above NE

